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New!

MEADE LX90

8" LX90

$1695

Now you can buy the telescope of a lifetime at a price you probably never thought possible!

The Meade 8" LX90, with diffraction-limited Meade® optics in an all-new Autostar™ computer-controlled telescope system, includes capabilities not available on competing 8" Schmidt-Cassegrains that cost hundreds of dollars more. And, at $1695, the 8" LX90 — *with more than twice the light-gathering power* — is priced only a few hundred dollars more than competing 5" Schmidt-Cassegrains!

Q: What is new and different about the Meade 8" LX90 Schmidt-Cassegrain?

A: The Meade 8" LX90 is the first full-capability, computer-controlled 8" Schmidt-Cassegrain ever offered in its price range.

Q: What do you mean by *full-capability?*

A: We believe that the great majority of amateur astronomers want their telescope not only to be a high-resolution visual observing instrument but also to be fully qualified for the more advanced areas of astronomy, including long-exposure CCD imaging and astrophotography. As detailed below, the LX90 meets all requirements in these areas.

Q: What features not included on competing telescopes enable the LX90 to meet these advanced requirements?

A: A few of these features include: (a) a die-cast-aluminum *double-tine* fork mount that rigidly supports the optical tube in all sky orientations; (b) *worm gears* of 4.9"-diameter on both telescope axes that permit smooth sidereal-rate tracking of celestial objects as well as precise guiding corrections during long-exposure imaging; (c) a chromed-steel variable-height tripod that provides all the rigidity required in sensitive field applications — *in fact, the same tripod as provided with Meade LX200 models.*

MEADE LX90 EMC
COMPUTER CONTROL
MEADE
ENTER
MODE
GO TO

Meade 8" LX90 Schmidt-Cassegrain Telescope — complete as shown with Autostar hand controller and variable-height field tripod — $1695.

Competing models include single-tine forks, spur-gear drives, and lightweight aluminum tripods suitable only for short-exposure planetary and terrestrial photos.

Q: Is the Autostar hand controller included as standard equipment with the LX90? What telescope operations are enabled by the Autostar?

A: The LX90's *standard-equipment* Autostar controller connects to the telescope's control panel and permits an incredible array of telescope options:

- Automatic GO TO capability at 6.5°/sec on both axes, simultaneously, to 30,223 database objects, including:

  13,235 deep-sky objects sorted by named objects; galaxies; diffuse nebulae; planetary nebulae; and star clusters; and including the complete Messier, Caldwell, IC, and NGC catalogs;

  16,888 stars sorted by name, SAO catalog numbers, double and variable stars; plus the centroids of the 88 constellations;

  50 objects in the solar system: 8 major planets from Mercury to Pluto; the Moon; 26 asteroids; 15 comets;

  50 Earth satellites, including the International Space Station, Hubble telescope, and Mir;

  plus 200 memory locations for user-defined objects.
- Automatic GO TO capability to *any* object of known R.A. and Declination.
- Nine selectable slew speeds: 6.5°/sec, 3°/sec, and 1.5°/sec, as well as 128x, 64x, 16x, 8x, 2x, and 1x sidereal.
- Control of the telescope through your personal computer, using the RS-232 serial interface.
- Hundreds of special event menus, guided tours, glossary, utility functions, and telescope status options.
- Fast alignment of the telescope in either equatorial or altazimuth modes using any of three alignment functions, including the Meade-proprietary Easy Align*.
- Unlike the hand controllers included with competing 5" and 8" SCT's (and which require disassembly of the telescope electronics for memory upgrade), *Autostar is fully upgradeable over the Internet*: the observer can add the positions of new comets, update the positions of Earth satellites, even add new software as it becomes available.

Q: How does the new 8" LX90 compare to the Meade 8" LX200? Which telescope should I buy?

A: For a great many observers the 8" LX90 is all the telescope ever required. The LX90 includes the exact same 8" f/10 optical system, including coatings, as the 8" LX200, so that the visual observing experience is identical in both instruments. Notwithstanding the many virtues of the LX90, however, we still recommend the LX200 for those amateurs who can afford the slightly higher price of the LX200 and who intend an extensive program of CCD imaging, astrophotography, or deep-space observing. The LX200's object database, at 64,359, is more than twice the size of the LX90's, and the LX200 slews at 8°/sec to a pointing precision of 2 arc-minutes or better, compared to the 5 arc-minute pointing precision of the LX90. The LX200 mounting, with its oversize fork arms, larger worm gears, and Smart Drive™, is the most advanced altazimuth-equatorial platform ever offered in a production 8" Schmidt-Cassegrain. The real answer to the question is that one can not go wrong with either telescope: the proper choice depends on the user's long-term applications and budget.

AUTOSTAR
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Dec = +66°48
MEADE
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The Autostar controller facilitates hundreds of LX90 telescope operations at the push of a button and includes a database of more than 30,000 celestial objects.

Q: How is the LX90 powered?

A: Power at 12 volts DC is provided by (user-supplied) C-cell batteries loaded through the upper surface of the telescope's drive base. Alternately, the telescope may be powered from an automobile cigarette lighter plug or from a standard 115vAC home outlet, using optionally available power cords.

*Patent pending.

Meade 8" LX90 at a Glance

Optics	8" f/10 Schmidt-Cassegrain
Coatings	Meade EMC Super Multi-Coatings
Mounting	Cast-aluminum, double-tine forks
Gears	4.9"-dia worm gears, both axes
Autostar Database	30,223 objects
Alignment	Altazimuth or equatorial, at user's option
Pointing Precision	5 arc-minutes in GO TO mode
Slew Speeds	1x sidereal to 6.5°/sec in 9 increments
Slow-motion controls	Electric, R.A. and Dec
Tripod	Variable-height field tripod
Accessories	8 x 50mm finder, 1.25" diagonal prism, Super Plössl 26mm eyepiece
Net telescope weight	31 lbs.
Net tripod weight	20 lbs.

SPECIFICATIONS: 8" LX90 — Each complete telescope includes 8" f/10 Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings; double-tine fork mount with dual-axis 4.9" worm gears and control panel; electric slow-motion controls on both axes; Autostar hand controller with digital readout display, 9-speed drive controls on both axes, and GO TO controller; 30,223-object onboard celestial software library; internal battery port accepts 8 (user-supplied) C-cells (optional 25 ft. cords permit powering from either 12vDC auto cigarette lighter plug or from 115vAC home outlet); 8 x 50mm viewfinder; 1.25" diagonal prism; Series 4000 Super Plössl 26mm eyepiece; standard field tripod; operating instructions. **$1695.** Packing & shipping in the 48 states: $95.

Price shown is suggested U.S. mail-order retail price.

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The light we see with our eyes is just a tiny fraction of the vast spectrum that astronomers must use to decode the universe. *James B. Kaler*

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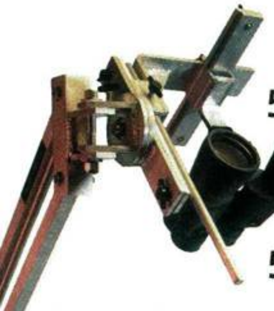

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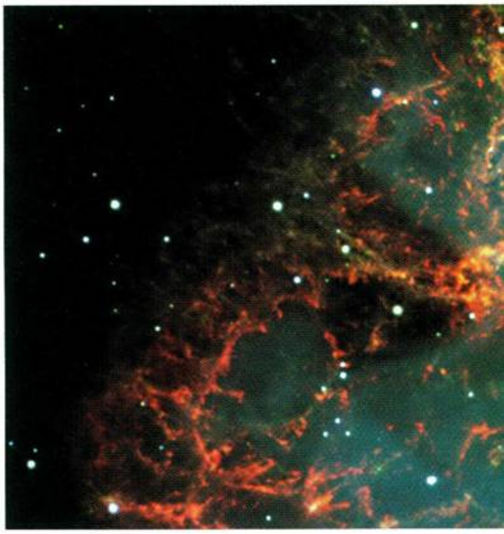

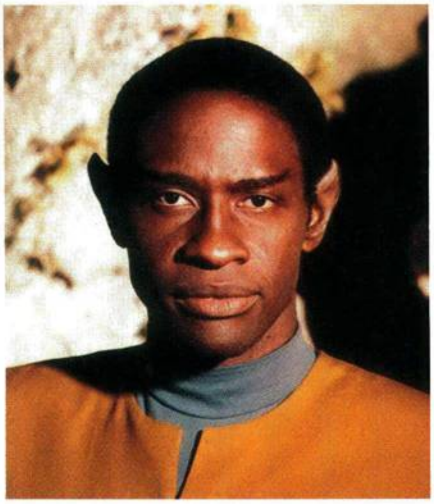

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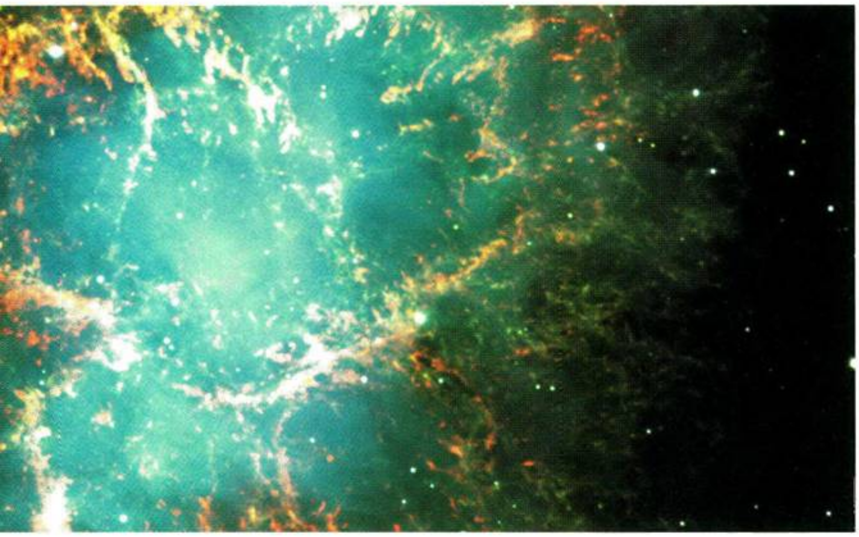

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From *The Glorious Constellations*, © 1991; Harry N. Abrams, Inc.

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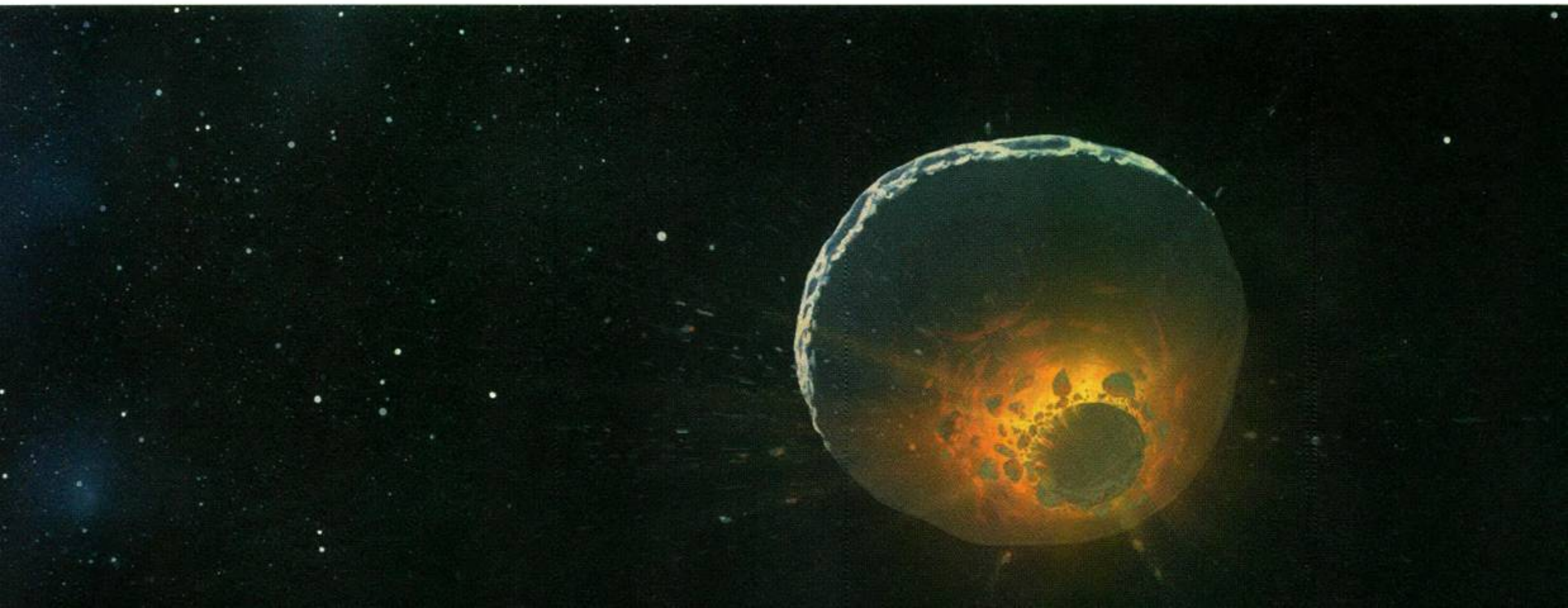


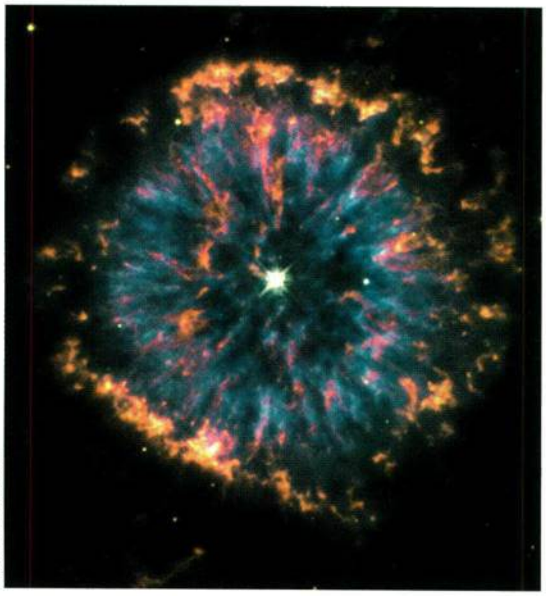
BEHIND THE SCENES

BY BONNIE BILYEU GORDON

Here's Looking at You

In the constellation Aquila, astronomers used the Hubble Space Telescope to create this picture of the unique and beautiful planetary nebula NGC 6751. Looking like an outsized eye, the nebula is a gas cloud that was thrown off thousands of years ago from the hot star you can see at center.

When solar-sized stars approach the ends of their lives, they begin to eject gas shells, or planetary nebulae, that often take magical shapes. Our sun could eject its own planetary nebula as soon as 6 billion years from now. Planetary nebulae were named before powerful telescopes were invented. Through smaller scopes of the period, they appeared as round greenish blobs, something like the planet Uranus, also recently discovered. Now we know planetary nebulae have nothing to do with planets.



NASA, STScI, AURA

NGC 6751

We had no special place set aside in this issue to include the big eye; there's no particular news story in the object, mostly beauty. We decided, however, that we couldn't leave it out. The Hubble observations were made in 1998 with the Wide Field Planetary Camera 2 by a team led by Arsen Hajian of the U.S. Naval Observatory. The Hubble Heritage team prepared this color rendition with the observing team's images and color filters.

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8" LX10

8" LX10 DELUXE

The optical performance of a Meade 8" LX200 Schmidt-Cassegrain...for only *$995!*

8" LX10: For the serious amateur astronomer on a more limited budget, or for the more casual observer who nonetheless demands the very finest in optical performance, the Meade 8" LX10 satisfies every requirement. *Standard-equipment includes:*

Super-Multi-Coated Optical System: The *exact same* multi-coated 8" Schmidt-Cassegrain optical tube assembly as more expensive Meade 8" LX50 and LX200 models. **Series 4000 SP26mm eyepiece:** Complements the exquisite imaging of Meade 8" SC optics. **Equatorial Fork Mounting:** The relatively light weight, but very stable, LX10 fork mounting provides all of the rigidity required for sensitive high-power applications of the telescope, or for photographic or CCD imaging. **Cordless, DC-Powered Electronic Motor Drive:** With electronically-regulated DC servo motor for automatic *sidereal-rate* tracking; powered by four AA-size batteries that fit conveniently through the telescope's control panel; battery life is in excess of 50 hours. **Worm-Gear System:** The LX10's 5.75"-diameter worm gear produces extremely smooth, regular motion in R.A., with low periodic error — a periodic error that permits such advanced capabilities as long-exposure astrophotography or CCD imaging. **Hand Controller:** Essential for micro-guiding the telescope during long-exposure astrophotography, the LX10's pushbutton hand controller enables precise corrections in R.A. at 2x speed. With the optional electric Declination motor added to the telescope, the hand controller is functional at 2x speeds on both telescope axes.

SPECIFICATIONS: 8" Model LX10 — Includes 8" Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings (D = 203mm; F = 2000mm, f/10); fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75" LX worm gear reduction system; sidereal-rate electronically-regulated DC servo motor drive; 4-pushbutton hand controller for 2x speed corrections in R.A.; battery compartment accepting four (user-supplied) AA-size batteries (telescope may also be powered from an auto cigarette lighter plug, using optional 25 ft. cord); 6 x 30mm viewfinder; eyepiece-holder and diagonal prism (1.25"); SP26mm multi-coated eyepiece; standard equatorial wedge with elevation scale, fine elevation control, and 360° azimuth orientation capability; complete operating instructions. **$995.** (+ $65 packing & shipping in the 48 states)

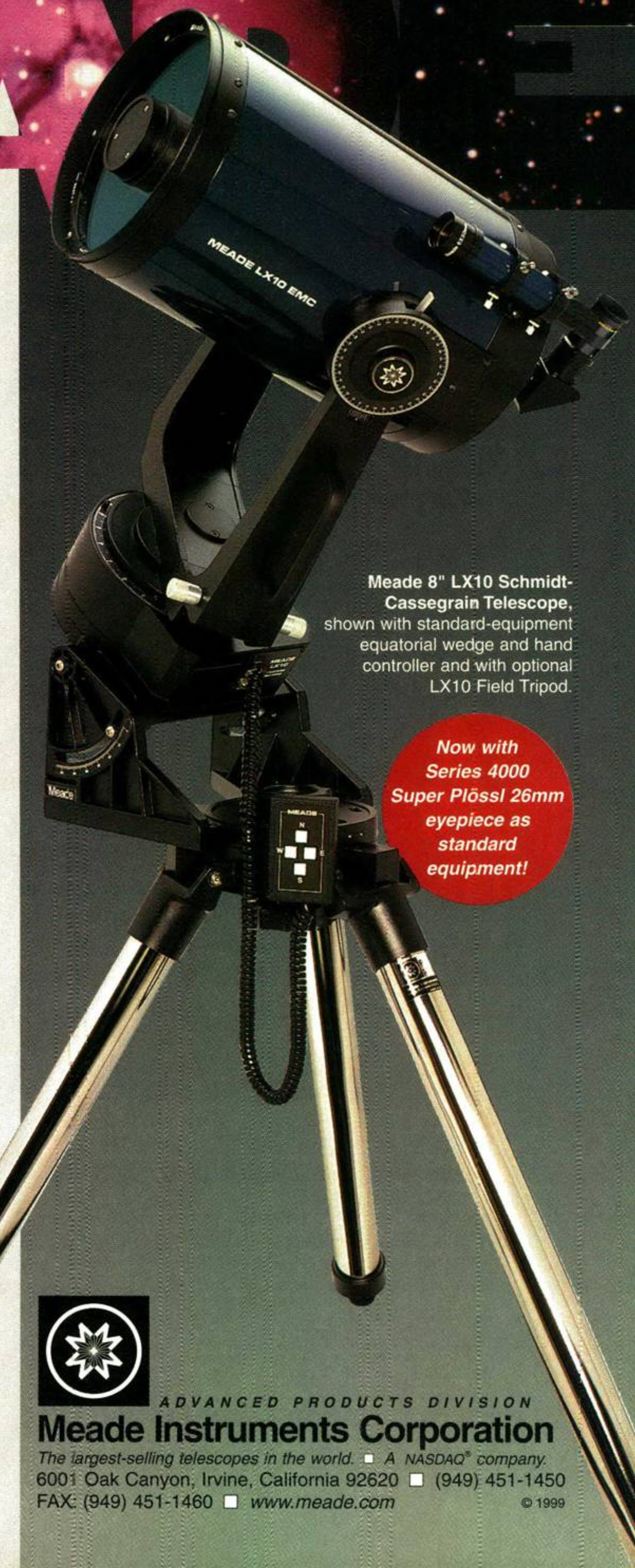
8" LX10 Deluxe: At only $1149 the 8" LX10 Deluxe includes (a) the large-aperture Meade #544 8 x 50mm viewfinder (in place of the standard 6 x 30mm finder); (b) the LX10 Electric Declination Motor System, permitting dual-axis guiding corrections at 2x speed; and (c) Meade Epoch 2000 Jr. Sky Software with 10,000-object database — all at substantially lower cost than if the respective accessories were purchased separately.

SPECIFICATIONS: 8" Model LX10 Deluxe — Identical in all specifications to 8" Model LX10, above, but with Electric Declination Motor System provided as standard equipment, permitting dual-axis corrections at 2x speed; Meade #544 8 x 50mm achromatic viewfinder in place of 6 x 30mm viewfinder; and Meade Epoch 2000 Jr. Sky Software with 10,000-object database.

$1149. (+ $65 packing & shipping in the 48 states)

Field Tripod for LX10 or LX10 Deluxe	195.
Electric Declination Motor System for LX10	95.
#2014 Magellan I Telescope Computer System for LX10 or LX10 Deluxe, with 12,218-object database	375.

The 120-page Meade General Catalog is available free of charge from Meade Instruments or from authorized Meade dealers.
Prices shown are suggested U.S. mail-order prices.



Meade 8" LX10 Schmidt-Cassegrain Telescope, shown with standard-equipment equatorial wedge and hand controller and with optional LX10 Field Tripod.

Now with Series 4000 Super Plössl 26mm eyepiece as standard equipment!

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MEADE LX200

8" LX200
$2295
10" LX200
$2695
12" LX200
$3995

The largest-selling serious telescopes in the world are now available at the most affordable prices *ever!*

The exact same LX200's as before: not one specification has been changed. **Compare a Meade LX200 feature-for-feature with competing single-tine-fork, spur-gear-driven, GO TO Schmidt-Cassegrains.** You'll see why there really is no comparision:

- **Superb Optics:** With oversize primary mirrors for greater full-field illumination, LX200 diffraction-limited imaging capabilities are a legend in the industry; we regularly receive reports stating that optical performance approaches that of a fine *ED* apochromatic lens.
- **Automatic GO TO Capability:** Competing 8" Schmidt-Cassegrains claim to place objects "somewhere in the field of view;" Meade LX200's place objects **dead-center** in the field of view, first time, every time, to a pointing precision of **2 arc-minutes or better,** or, with Meade-exclusive High Precision Pointing, to a precision of **one arc-minute or better.** *Meade LX200's are the only commercial telescopes ever manufactured that automatically GO TO any input R.A. and Dec., or to any object in the onboard database, to these levels of precision.*
- **Database of 64,359 Objects,** a database *more than three times larger* than competing GO TO telescopes.
- **Permanently-Programmable Smart Drive™** routinely achieves 5 arc-sec. periodic error, an observatory standard. Competing GO TO 8" SCT's decline to state their periodic error and do not offer any programmable error-corrector.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every contingency of telescope posi-

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MEADE LX200 EMC
MEADE LX200
SMART DRIVE
Meade
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Meade 8" LX200 Schmidt-Cassegrain Telescope — now $2295, complete.

tioning — from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between. Competing 8" SCT's slew only up to 6.5°/sec.

- **Rigid LX200 Dual-Tine Fork Mountings with Dual 5.75" Worm Gears** are the choice of advanced observers, CCD imagers, and astrophotographers for their most sensitive applications. Competing spur-gear-driven single-tine forks can not approach the strength, rigidity, and drive-rate precision built into every Meade LX200 mounting.
- **Full Long-Exposure Capability:** Competing 8" GO TO telescopes describe their capability to take short-exposure "planetary and terrestrial photos," without reference to any long-exposure capabilities. Meade LX200's have been the instruments of choice in **thousands** of the most detailed long-exposure images ever taken by amateur astronomers.
- **Strong Field Tripods:** Unlike the thin, extruded aluminum tripods of competing models, every LX200 includes a fully adjustable steel field tripod perfectly suited to the sub-arc-second resolution of the telescope's optics.

"…Viewing a 2nd-magnitude star at high power [the 8" LX200] showed a nearly textbook-perfect image…I do indeed rank these optics as diffraction limited…Jupiter and Saturn exhibited riveting detail… During the November 10, 1997, triple shadow transit on Jupiter, the LX200 was my telescope of choice. It showed all three moon shadows as plainly different in size and shading, a rare and remarkable sight. Under the automatic GO TO command, the LX200 routinely placed objects, including the Moon and planets, within 1 to 4 arc-minutes of the center of the field. Not only was it accurate — it was fast. The LX200 usually took no longer than 10 to 25 seconds to slew to and center an object…The latest major feature added to the system is what Meade calls High Precision Pointing. When this is activated…Meade promises a pointing accuracy of 1 arc-minute. I can confirm this amazing figure. Objects consistently ended up within 1 to 2 arc-minutes of the field's center, a great aid to CCD imaging of faint targets…if you know what you want to look at, the LX200 will find it with astonishing speed and accuracy…the telescope I tested provided excellent performance in all critical areas while adding a level of technical luxury that is truly powerful and impressive…I have absolutely no hesitation in recommending the LX200 series…After having used the LX200 for several months, I can attest to the wonderful hands-off convenience and sheer fun of the motorized GO TO." — **from the review in *Sky & Telescope*, April, 1998.**

"The [10" LX200] telescope's optics, stability, and tracking accuracy — all of which are crucial in my applications — are truly remarkable, fully up to the demands that my photographic program requires. My LX200 is now nearly four years old, and during that time it has received heavy use, including 2000-mile round trips to southern France four times a year. The telescope is everything I could possibly have expected it to be." — **Philip Perkins, Wiltshire, England**

The Whirlpool Galaxy (M51) in Canes Venatici.
A 10" LX200 photo by Philip Perkins; two 120-minute exposures were digitally combined to obtain the final image.

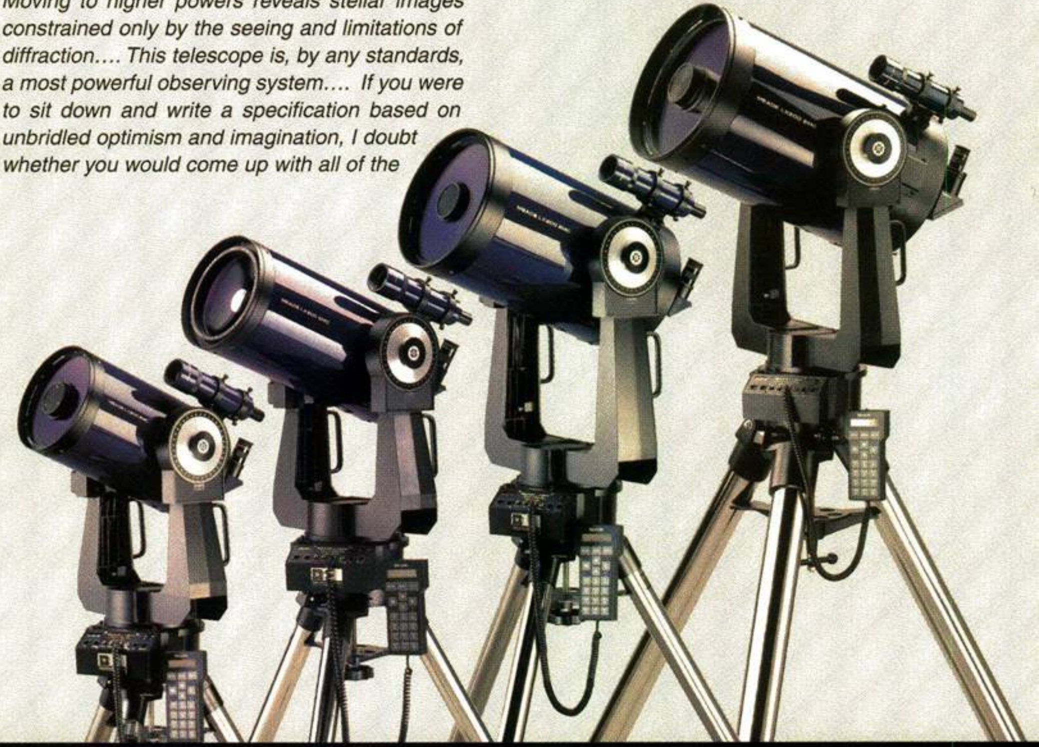
"The view through the [7" LX200] system is superb, with pin sharp images right across the field and absolutely no trace of achromatism. Moving to higher powers reveals stellar images constrained only by the seeing and limitations of diffraction…. This telescope is, by any standards, a most powerful observing system…. If you were to sit down and write a specification based on unbridled optimism and imagination, I doubt whether you would come up with all of the features available on the LX200 series. This telescope really has to be experienced." — **from the review in *Astronomy Now (U.K.)*, November, 1996, by Bob Neville, Director, Instruments and Imaging Section, British Astronomical Association.**

"The optics of my 12" LX200 are exquisite — in fact the best optics in a commercial catadioptric telescope that I have ever looked through. At 500X the Epsilon Lyrae double-double is not only clearly split into four components, but each of the four stars exhibits a textbook-perfect diffraction pattern, the ultimate test for superior optics." — **Jack Newton, Chiefland, FL.**

SPECIFICATIONS: 7", 8", 10", and 12" LX200's — Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC (optional #1812 Electronic DC Adapter allows for field powering directly from an automobile cigarette lighter plug); 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

8" LX200 Schmidt-Cassegrain	**$2295.**
10" LX200 Schmidt-Cassegrain	**2695.**
12" LX200 Schmidt-Cassegrain	**3995.**
7" LX200 Maksutov-Cassegrain	**2795.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125. Prices shown are suggested U.S. mail-order retail prices and are effective March 15, 2000.



New 2000 120-page Meade General Catalog!

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ADVANCED PRODUCTS DIVISION

Meade Instruments Corporation

World's Leading Manufacturer of Astronomical Telescopes for the Serious Amateur

6001 Oak Canyon, Irvine, California 92618 ■ (949) 451-1450
FAX: (949) 451-1460 ■ *www.meade.com*

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New!

Now you can join the ETX revolution for as little as $299, complete!

MEADE ETX-60AT • ETX-70AT

Let Meade high-resolution ETX optics and standard-equipment Autostar controller take you on an automated guided tour of the Solar System, the Galaxy, and beyond. Now even the most novice amateur astronomer can locate and explore the planets, asteroids, and comets, as well as nebulae, star clusters, galaxies, and hundreds of other deep-space objects, at the push of a button.

Fork Mount with Dual-Axis Drive System: In conjunction with the Autostar hand controller, precision worm gear systems on each axis permit smooth pushbutton motions of the telescope, as well as sidereal-rate tracking in the altazimuth mode.

Standard-Equipment #494 Autostar™ Controller: The #494 Autostar includes most of the same features as the more advanced #497 Autostar available for larger Meade ETX models *(facing page)*.

- **Automatic dual-axis GO TO function at 4.5°/sec.** to any of more than 1450 database objects, including the complete Messier and Caldwell deep-space object catalogs, the major planets from Mercury to Neptune, 26 asteroids, 15 periodic comets, and more.
- **Select any of Autostar's** database objects, or any object of known R.A. and Dec, press ***GO TO*** and the telescope automatically slews to the object, placing it in the telescopic field of view.
- **Digital readouts** of telescope position, continuously in R.A. and Dec.
- **9-speed Dual-Axis Operation:** Pushbutton control of the telescope on both axes, simultaneously, at any speed from 2x sidereal to 4.5°/sec., plus sidereal-rate tracking.

High-Resolution Achromatic Objective Lenses: ETX 60mm and 70mm models include multi-coated, air-spaced achromatic lenses of exclusive Meade design; each lens yields razor-sharp images of astronomical and terrestrial subjects.

Flip-Mirror System: Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #933 45° Erecting Prism or for photography with the optional #64ST Photo Adapter.

Cordless Operation: The dual-axis drive of Meade ETX-60AT and ETX-70AT models operates for over 20 hours in the field from six AA-size (user-supplied) batteries which store neatly inside the drive base.

Solar System: Saturn
ENTER
MODE
GO TO
SPEED
MEADE AUTOSTAR
Guided Tour Tonight's Best
ENTER
MODE
GO TO
SPEED
MEADE AUTOSTAR
MEADE
COMPUTER CONTROL
OFF
ON
AUX

ETX-70AT: $349, complete with #494 Autostar Controller.

ETX-60AT: $299, complete with #494 Autostar Controller

SPECIFICATIONS: ETX-60AT and ETX-70AT Astro Telescopes — Each includes achromatic refractor optical tube assembly (D = 60mm, F = 350mm, f/5.8 *or* D = 70mm, F = 350mm, f/5) with multi-layer optical coatings; internal flip-mirror system for either straight-through or 90° observing position; fork mount with electric slow-motion controls, setting circles, and locks on both axes; electronic control panel; 9-speed (2x sidereal through 4.5°/sec.) dual-axis motor drive system with #494 Autostar computer controller; sidereal-rate tracking; internal battery compartment accepting six (user-supplied) AA-size batteries; MA9mm (39X) and MA25mm (14X) multi-coated eyepieces; operating instructions. **ETX-60AT — $299** (+$10 packing & shipping in the 48 states); **ETX-70AT — $349** (+$10 P & S).

OPTIONAL SYSTEMS FOR MEADE ETX TELESCOPES*

#882 Standard Field Tripod (60, 70)	$99.00	#883 Deluxe Field Tripod (90, 125)	199.95
#827 8 x 25mm Right-Angle Viewfinder (60, 70)	49.95	#825 8 x 25mm Right-Angle Viewfinder (90)	49.95
#773 Hard Carry Case (60, 70)	59.95	#774 Hard Carry Case (90)	99.95
#933 45° Erecting Prism (60, 70)	49.95	#775 Hard Carry Case (125)	149.95
#64ST Photo Adapter (60, 70)	19.95	#932 45° Erecting Prism (90, 125)	49.95
#497 Autostar Computer Controller (90, 125)	149.00	#64 Photo Adapter (90, 125)	34.95
#880 Equatorial Table Tripod (90)	29.95	Electric Focuser #1244 (90) *or* #1247 (125)	119.95
#881 Equatorial Table Tripod (125)	59.95		

**see also the Meade accessory ad in this issue.*

MEADE INSTRUMENTS CORPORATION *The largest-selling telescopes in the world.*

MEADE ETX-90EC • ETX-125EC

COMPUTER CONTROL
MEADE
FOCUS
IN
OUT
SPEED
MODE
MEADE

ETX-90EC: $595, complete with Electronic Controller

ETX-125EC: $895, complete with Electronic Controller

SPECIFICATIONS: ETX 90EC and ETX-125EC Astro Telescopes — Each includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8 *or* D = 127mm, F = 1900mm, f/15) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; fork mount with electric slow-motion controls, setting circles and locks on both axes; electronic control panel; 4-speed (8x, 32x, 0.75°/sec, 5°/sec) dual-axis motor drive system with hand controller; sidereal-rate tracking in equatorial mode with optional table tripod or deluxe field tripod; internal battery compartment accepting eight (user-supplied) AA-size batteries; 8 x 21mm erect-image (ETX-90EC) *or* 8 x 25mm right-angle (ETX-125EC) viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); instructions. **ETX-90EC — $595** (+ $20 packing & shipping in the 48 states). **ETX-125EC — $895** (+ $30 P & S).

AUTHORIZED U.S. AND CANADA MAIL-ORDER DEALERS

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 925-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

POCONO MOUNTAIN OPTICS, Moscow, PA.
Orders: 800-569-4323; Info.: 570-842-1500.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 847-367-4600.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

6001 Oak Canyon, Irvine, CA 92618. (949) 451-1450. FAX: (949) 451-1460. www.meade.com

Two advanced apertures:
ETX-90EC — $595
ETX-125EC — $895

Meade® 3.5" and 5" ETX® models include the very latest in microprocessor-controlled capability:

Fork Mount with Dual-Axis Drive System: Each with high-torque DC motors on both telescope axes, permitting electronic operation from the standard-equipment plug-in hand controller.

Pushbutton Electronic Hand Controller: Use at any of four dual-axis speeds: 8x for image centering at high power; 32x for image centering at lower power or for pushbutton object-tracking in the altazimuth mode; 0.75°/sec for image centering in the viewfinder or for terrestrial tracking; 5°/sec for fast slewing across the sky.

Maksutov-Cassegrain Optical Systems: Manufactured at the Meade Irvine, facility, ETX diffraction-limited optics produce images so high in contrast and resolution that ETX telescopes often outperform other telescopes of larger apertures.

Flip-Mirror System: Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #932 45° Erecting Prism or for photography with the optional #64 Photo Adapter.

Cordless Operation: The dual-axis drive system operates for more than 40 hours from eight (user-supplied) AA batteries which store neatly inside the drive base.

Optional #497 Autostar™ Capability: Plug in the optional Meade #497 Autostar computer controller for LX200-type operation, including:

- **Automatic dual-axis GO TO function at 5°/sec** to any of more than 14,000 database objects, including deep-space objects (galaxies, diffuse nebulae, planetary nebulae, star clusters); the 8 major planets from Mercury to Pluto; 26 of the brightest asteroids; 15 periodic comets; and more.
- Select any of Autostar's database objects, or any object of known R.A. and Dec, press ***GO TO*** and the telescope automatically slews to the object, placing it in the telescopic field.
- **Digital readouts** of telescope position, continuously in R.A. and Dec.
- **9-Speed Dual-Axis Operation:** Pushbutton control of the telescope on both axes, simultaneously, at any speed from 2x sidereal to 5°/sec., plus sidereal-rate tracking.

ETX AUTOSTAR
MEADE
ENTER
MODE
GO TO

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MEADE

RESEARCH-GRADE ACCESSORIES

Series 4000™ Super Plössls
52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$79.95** (4.54)
32mm (52°); **40mm** (44°)	each:	**99.95** (5.26)
56mm (52°; 2")		**199.95** (7.02)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (5.26)

Series 4000™ Super Wide Angle
67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

Series 4000™ Ultra Wide Angle
84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (5.26)

Series 3000™ Plössls
50° field; multi-coated

Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm *(far right in photo)*, an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.86); **40mm** (44° field): **$79.95** (3.86)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. **$129.95** (5.26)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue each **$14.95** (2.73)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (4.54)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (4.54)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.73)

#911B
#910B
#908B

#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (4.54)
#910B–Threads into 2" eyepieces, 44mm dia.	**119.95** (5.26)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (5.26)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (4.54)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (5.26)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (5.26)

#911X
#910X
#908X

Series 4000 Oxygen-Ⅲ Filters Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade *60-layer* interference coating technology isolates the 496nm and 501nm O-Ⅲ lines to tremendously enhance observable nebular structural detail in all telescopes.

#908X–Threads into 1.25" eyepieces, 26mm dia.	**99.95** (4.54)
#910X–Threads into 2" eyepieces, 44mm dia.	**159.95** (5.26)
#911X–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**149.95** (5.26)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (4.54)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (5.26)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (4.54)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (4.54)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

#929 or **#930,** each: **$99.95** (6.85)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.86)

Electric Focusers for SCT's

For extremely smooth microfocusing of the image. Does not affect use of the manual coarse-focus knob.

#1206 Electric Focuser: Plugs into control panel of Meade 8", 10", 12" LX200 models and operates from LX200 hand controller. **$149.95** (7.48)

#1205 Electric Focuser: For **all** other Meade 8", 10", 12" SCT models; includes separate hand controller; accepts one self-contained (user-supplied) 9v. battery.

$169.95 (7.88)

#777 Off-Axis Guider for SCT's

Internal prism diverts light for monitoring telescopic image during long-exposure astrophotography. Threads to any Meade or Celestron rear cell. Use with illuminated reticle eyepiece and T-Mount for your 35mm camera.

$79.95 (6.85)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (4.54)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". **Batteries included.**

$99.95 (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (5.26)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": $27.95; **1.25": $29.95** (3.86)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (3.86)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (3.86)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (3.86)

CCD-Photo-Visual Flip-Mirror Systems

An essential accessory for imaging with ***any*** brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment screws and locks for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for attaching either 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

"Over the past 10 years I have used all manner of flip-mirrors. The Meade Flip-Mirror Systems are absolutely the best—rock solid, high-precision, beautifully manufactured; they virtually eliminate all flexture between the CCD and telescope." — Jack Newton

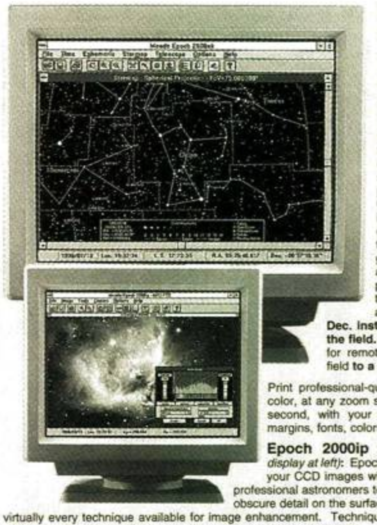
#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XT or ST-7, or smaller; or visual observing with 1.25" eyepieces. **$149.95** (7.02)

#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XT, as well as ST-4 through ST-8; or for visual applications with 1.25" or 2" eyepieces. **249.95** (8.49)

#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.) **15.00** (3.86)

#644

#647



Epoch 2000® Sky Software

The most powerful astronomical software ever made available can now be yours for only $149!

Epoch 2000sk *(upper display at left)*: Now you can use the most advanced, most precise full-color sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** With star positions displayed as precisely as **0.01 arc second,** the Trapezium in Orion is no longer shown as a single point, as in other software, **but as four precisely oriented starpoints, just as they appear in the telescope.** No longer do you need to guess the R.A. and Dec. of an object located away from the field center, as in other programs: Epoch 2000sk dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely!

Print professional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

Epoch 2000ip Image Processing Software *(lower display at left)*: Epoch 2000ip makes it easy to enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet. This powerful software includes virtually every technique available for image enhancement. Techniques that bring out detail totally invisible in your original image, transforming it from the ordinary to the spectacular.

EPOCH 2000sk Sky Software: 281,000 objects supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 .... **$149**

EPOCH 2000sk-CD Sky Software: 19 million objects, including the complete Hubble Guide Star Catalog; supplied on CD-ROM **179**

LX200 Interface Cable: for Meade LX200 operation by Epoch 2000sk **25**

EPOCH 2000ip Image Processing Software: Supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 .... **$199**

f/3.3 CCD FOCAL REDUCER

Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

NEW!

Revolutionary 3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2.** Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated; 41mm clear aperture. **$149.95** (5.26)

Plössl 25mm Illuminated Reticle CCD Framing Ocular

NEW!
MEADE
PLÖSSL
CCD FRAMING

Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models and ST-4 through ST-8. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror *(above)*. Includes 4-element coated Plössl optics; lockable spacer ring to fix focus position; rubber eyecup; variable LED illumination control; batteries. 1.25". **$129.95** (4.54)

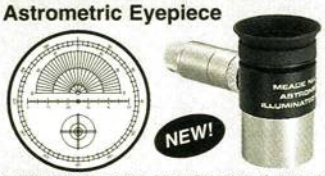
#825 8 x 25mm Right-Angle Viewfinder for ETX-90

Permits comfortable right-angle viewing. Replaces standard-equipment finder on 90mm ETX models, using the same bracket. Wide-angle, achromatic, coated optics; actual field 7.5°. Precise helicoid focusing. **$49.95** (4.26)

#64 T-Adapter for ETX®

Threads to the photo port of all ETX-90 and ETX-125 models. Rigidly couples any 35mm camera with removable lens to the telescope for lunar, planetary, or terrestrial photography. Includes extension tube for longer effective focal length, if desired. Use with T-Mount for your 35mm camera. **$34.95** (3.86)

MA12mm Illuminated Reticle Astrometric Eyepiece



A high-precision eyepiece for a wide range of astronomical measurements. Includes four red-illuminated, laser-etched scales for measuring double star angular separations, position angles, planetary diameters, and lunar crater diameters, and for long-exposure photo-guiding. Modified Achromatic 3-element coated optics; diopter adjustment; rubber eyecup; variable LED illumination control; batteries. 1.25". **$119.95** (4.26)

Series 4000™ 8mm – 24mm Zoom Eyepiece

NEW!

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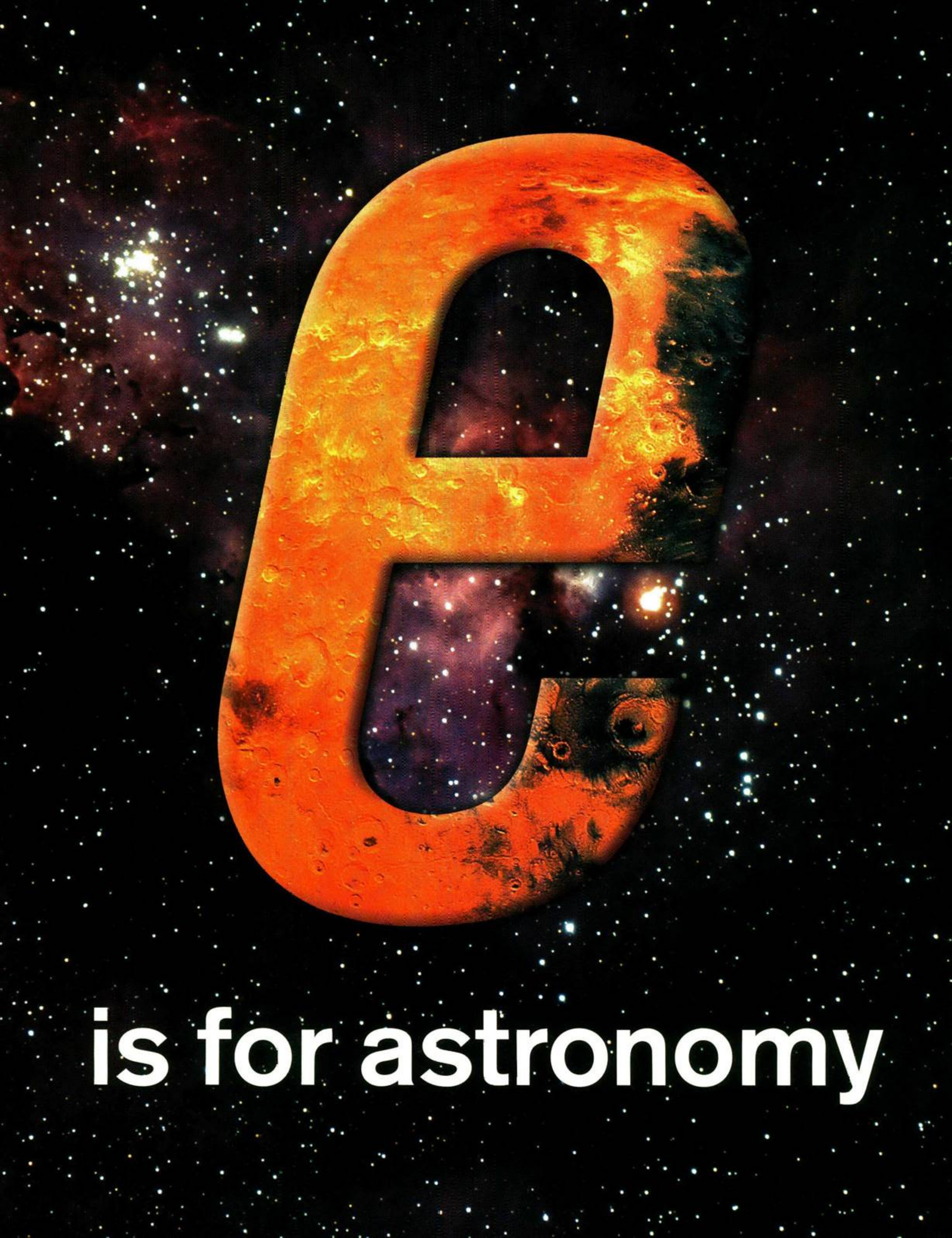
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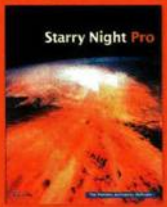

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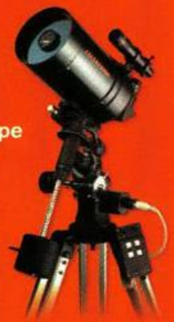

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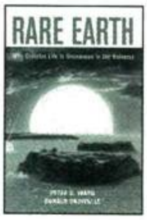

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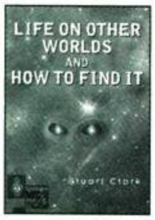

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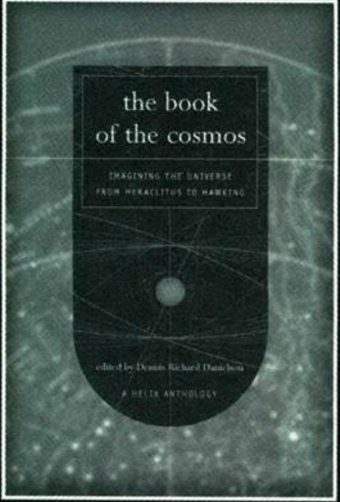
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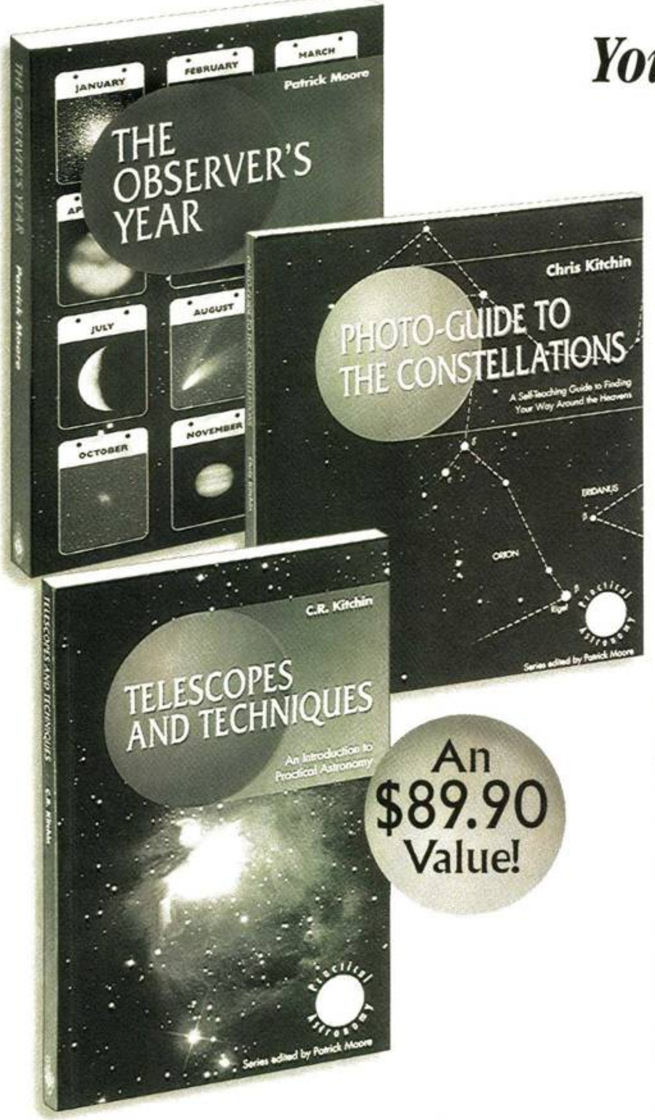
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TALKING BACK
FROM OUR READERS

Looking Up South

Earth is always drawn with the North Pole up. Why? — *Frank Fouche, Johannesburg, South Africa*

The choice of north as "up" is completely arbitrary — probably because all the "civilizations" that looked at such things until the last few centuries lived in the Northern Hemisphere. (It's the same reason that "clockwise" is the way it is. Sundials in the Southern Hemisphere move in what we northerners call a counterclockwise direction.) — Richard Talcott, associate editor

Daniel Gardiner

Omega Centauri (NGC 5139) is among the treats for Southern Hemisphere stargazers.

Southern Grandness

Yes, south is best! The June 2000 issue of *Astronomy* called it right. I'm originally from Ohio but now live in a remote village in South America without 24-hour electricity. The clear night sky goes on and on. There is an overall grandness to the southern Milky Way that steals the show. Some of my favorites include: The "Jewel Box" NGC 4755 open cluster in Crux, the Omega Centauri globular, the Keyhole Nebula of Eta Carinae, and the Large Magellanic Cloud in Dorado and Mensa. Anyone serious about astronomy who lives in the Northern Hemisphere just has to fly south sometime for a look. — *Michael L. Brown, Bolivia, South America*

No Contest

Bravo for the scorecard on south vs. north (June 2000) deep-sky viewing. Maybe now the largely northern readership of *Astronomy* will finally open its eyes to the truth about the southern skies. My only criticism of these judgments is *Astronomy*'s rating of M13 as third behind Omega Centauri and 47 Tucanae. Sorry, but M22, NGC 6397, NGC 6752, M4, and M5 are all superior objects. M13 runs 8th in my book.

As far as the top 20 globulars go, only two from the north (M13 and M15) make my list. Don't argue with me — I've seen 152 of them! Try doing that from anywhere in the Northern Hemisphere.

Meanwhile, I'd like to suggest two more categories for rating:

Supernova remnants — A small category that the north wins by a mile with M1 and the Veil. Southern skies have little to compare.

Naked-eye view/aesthetics — Just about everything in the southern sky is brighter, better, and more detailed. For us, the very best parts of the naked-eye Milky Way culminate high, if not overhead. Sorry to say to you Northerners, but the Cygnus to Cassiopeia area just can't compete against the whole swath from Puppis through Vela, Carina, Centaurus, Norma, Scorpius, Sagittarius, and Aquila. — *Les Dalrymple, Sydney, Australia*

Rallying Point

In the article "Captured By Aliens" (July 2000), Joel Achenbach reports that one of the Mars Society's beliefs is that young people will rally around the colonization of Mars. As a 16-year-old high school student, I feel that Earth already has many rallying points for my peers and me: the environment, racial tolerance and equality, famine, disease, religious persecution, etc. We need to fix those problems now — not take them into space with us. — *Jennifer Baker, Shelton, Connecticut*

Planetarium Falls Short

In "New York's New Eye to the Sky" (July 2000), Beth Livermore gave the Hayden Planetarium an undeserved favorable review. In my opinion, this planetarium appears rushed to construction in every aspect. The information "walls" are disjointed and difficult to follow, especially for beginners. The IMAX show and Big Bang Theater present hasty, special-effects-heavy blurbs that leave amateurs like me scratching our heads. Casual visitors may find the 13-billion light-year walk and breakdown of universal size fascinating but not compelling. For seven years, astronomers have had one of the greatest public relations devices ever seen in the Hubble Telescope images, yet I was hard-pressed to find any of these. I would add a wing of mural-sized blowups of the Eagle Nebula, Andromeda Galaxy, etc., and watch the public fascination really blossom. — *Erich Heckscher, Birmingham, Alabama*

Dark Skyland

I was elated at the vast tracts of dark sky evident in southeastern

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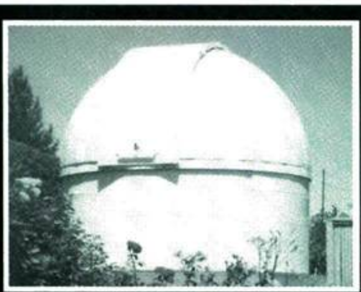

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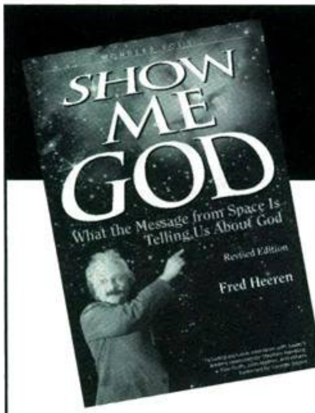

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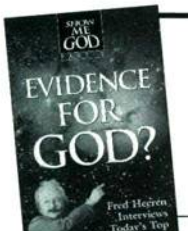

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Oregon, as indicated on the light pollution image of the U.S. on page 16 of the July 2000 issue.

Stargazers considering potential viewing sites near my area should visit Steens Mountain. At 9,773 feet above sea level, it's accessible from the west and is an ecological delight. — *Douglas K. Howard, Brookings, Oregon*

Booked Up

"Astronomy by the Book" (July 2000) reminded me of my own experience. I, too, started reading very young. Among my favorites was a textbook of my father's, called the *Manual of Astronomy.*

I skipped the mathematical part and concentrated on the descriptions. I memorized other parts. Then my father took me to the Naval Observatroy in Washington. When the guide showed us a Herschel eyepiece, I piped up, "Yes, it eliminates 90 percent of the light and heat;" the guide almost exploded — I was only eight years old!

So never underestimate your child. When he or she is four, buy a book for 4 to 8-year-olds, but also buy a book for 8 to 12-year olds. Also, encourage curiosity with the purchase of a spyglass-type telescope. Your child can use it day or night. — *W. E. Railing, Green Valley, Arizona*

Cheaper, Faster ≠ Better

Abundant discussions on NASA's recent failures direct blame to "cheaper and faster," but no one comments on the sly culprit, "better." Why not? Whoever conceived this folly should silently slink away. — *Fred Bassetti, Seattle, Washington*

Correction

The website for the Astronomy Internet Master's (AIM) program website is: http://www.nepean.uws.edu.au /astronomy/aiminfo.html.

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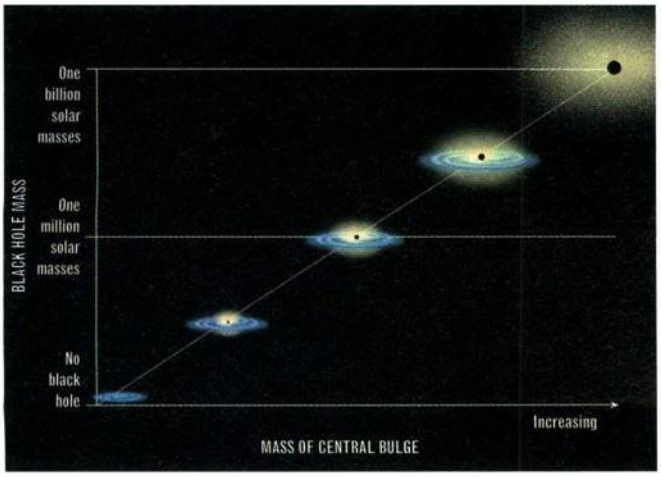
Astronomers at the June meeting of the American Astronomical Society (AAS) in Rochester, New York, reported the discovery of eight new supermassive black holes, bringing the total known to 33. The large sample size permits astronomers to say with relative certainty that big black holes and their respective host galaxies fit an intriguing pattern suggesting that black holes and galaxies grow conjointly rather than separately and merge later.

Karl Gebhardt from the University of California at Santa Cruz and John Kormendy from the University of Texas at Austin reported at the AAS meeting that all the black holes, ranging in size from a few million to 2.4 billion times the mass of the sun, "weigh" 0.2 percent of the mass of the parent galaxy's central bulge. Without exception, as the central bulge of a galaxy increases in mass, the black hole grows by the same proportion. (Those spiral galaxies lacking central bulges of stars don't appear to contain supermassive black holes.)

What is responsible for the 0.2-percent relationship? Nobody knows. However, Rutgers University astronomer David Merritt suggested at the meeting that the first galaxies may have formed when huge clouds of gas collapsed. The same collapse could also yield black holes. Quasars, the furiously radiating signatures of gas and stars falling into the black holes of these young galaxies, may throttle the black holes' growth with an outward pressure of energy given off in the accretion process. "The infall of gas might be self-regulating," says Merritt.

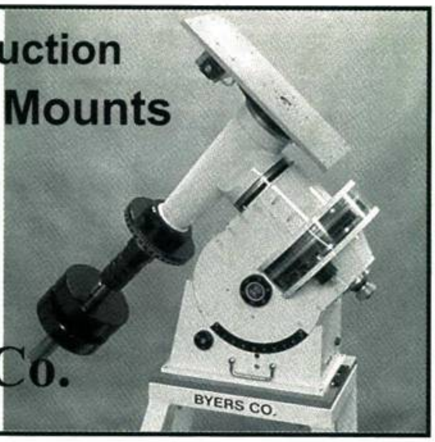
The mass of a supermassive black hole at the center of a galaxy is directly related to the mass of its host galaxy's central bulge. K. Cordes and S. Brown (STScI)



The spiral galaxy M81, which lies 12 million light-years from Earth, has a black hole weighing 63 million solar masses. N.A. Sharp/AURA/NOAO/NSF

Gebhardt and Kormendy reported another relationship between black holes and their host galaxies: While studying stars in the bulges that were located too far away to be gravitationally influenced by their galaxy's black hole, the researchers found that the stars, nevertheless, move at speeds precisely proportional to the size of the black hole. "With such a scaling law, there must be something going on," says Gebhardt.

He and Kormendy argued at the meeting that the galaxies with supermassive black holes initially collapsed to exceptionally small sizes, which in turn squeezed the stars closer together and gravitationally propelled them to orbit faster. "The major events that made the bulge and the major periods of black-hole growth were the same events," says Kormendy. "Galaxy formation directly results in the black hole feeding that makes quasars shine." — Rex Graham



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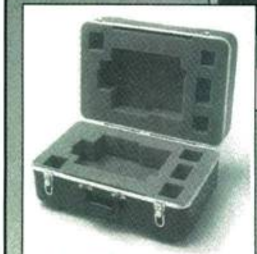

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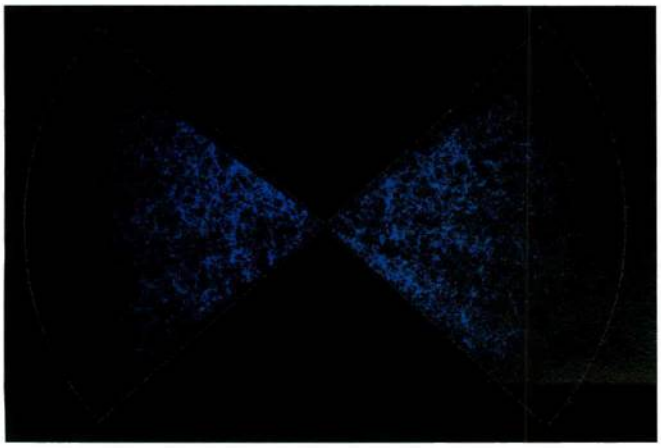
The team used the Anglo-Australian Telescope in New South Wales, a wide-angle telescope with a 2° field (2dF) of view, which is four times the diameter of the full moon. A robot inside the telescope places each of 400 hair-like glass fibers in position to simultaneously obtain light from individual galaxies. By measuring how much the light from each galaxy is Doppler shifted to longer (redder) wavelengths, the astronomers find how far away each galaxy lies from Earth — the farther away the galaxy, the faster the expansion of the universe carries it away from Earth and the more its light is redshifted. The 2dF Galaxy Redshift Survey eventually will map the positions of 250,000 galaxies. (The Sloan Digital Sky Survey, a North American mapping experiment with similar goals, is in the process of mapping about 1 million galaxies.)

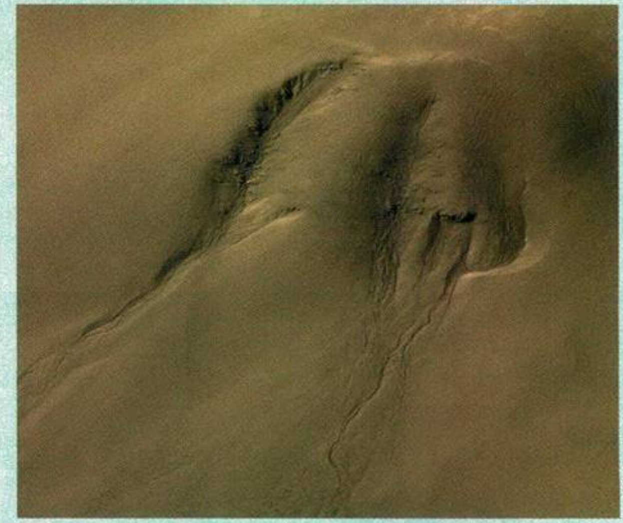
An analysis of the motions of galaxies in the 2dF map, reported at the June meeting of the American Astronomical Society in Rochester, New York, should help those worried that the universe might one day collapse. The 2dF results imply that the density of matter in the universe is less than the so-called critical value and the universe will continue to expand. If the measured density of matter had been greater than the critical value, the survey would have indicated that the universe is headed for a "big crunch" finale.

Two recent balloon experiments — BOOMERANG and MAXIMA — that studied the microwave radiation left over from the Big Bang suggest that the universe is "flat" (see "Unveiling the Flat Universe," August 2000). A flat universe expands forever and light travels through it along relatively straight lines. "There is no great cosmic discrepancy between our results and the balloon experiments," says Gavin Dalton, an astronomer at Oxford University and a member of the 2dF team. "The balloon experiments measure the total density of matter and energy, whereas the galaxy survey measures only the matter content." The difference is the energy density of the vacuum itself, also called the cosmological constant, or quintessence. The combination of the two types of experiments measures the value of this constant, and that result is consistent with those reported during the past two years from observations of supernovae located at great distances from Earth. — R. G.



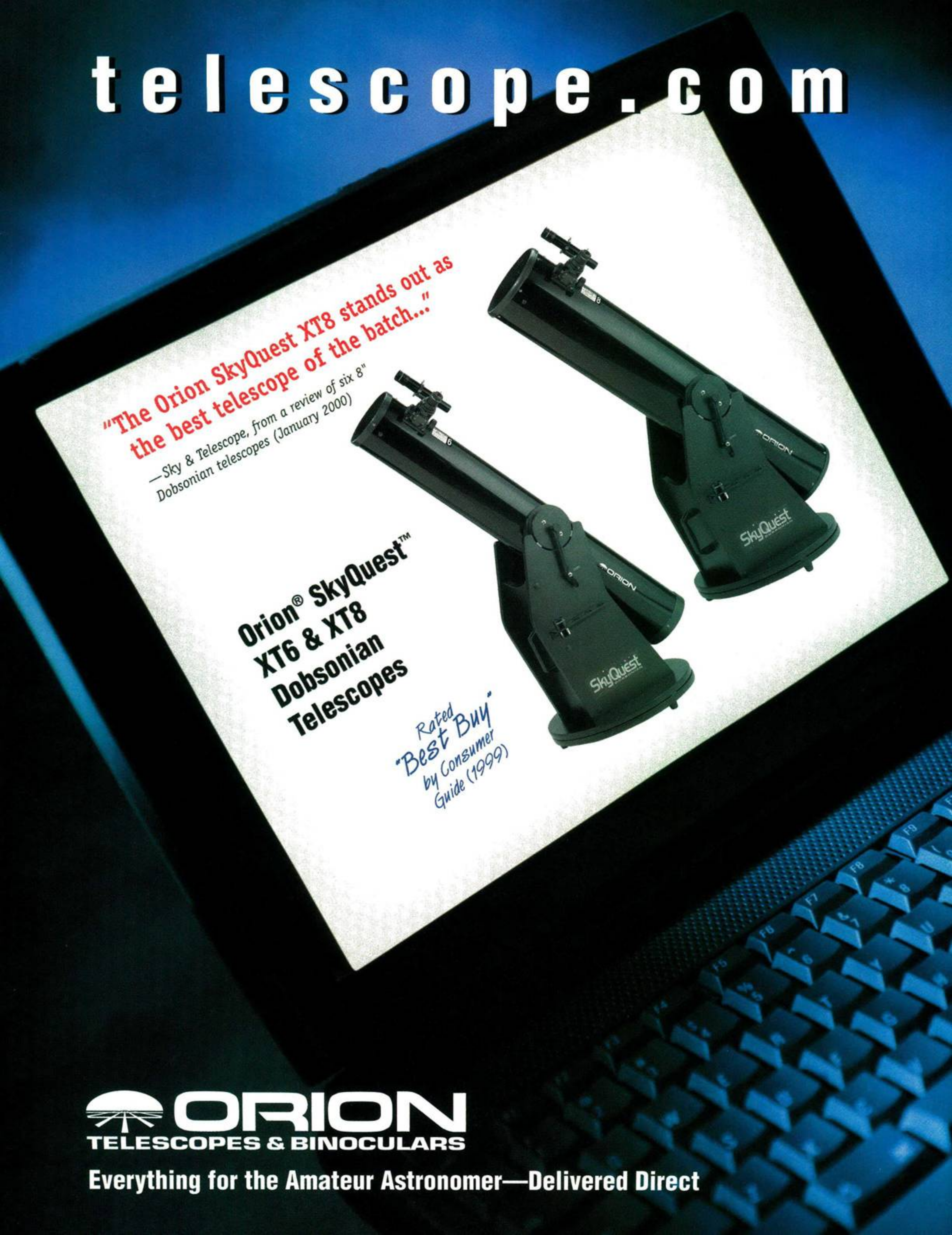
The 2dF galaxy redshift survey shows a universe with long chains of galaxies, giant superclusters, and enormous voids. Matthew Colless (ANU), et al., 2dF Galaxy Redshift Survey

WATER ON MARS



NASA/JPL/MSSS

IT MAY NOT BE A DAY AT THE BEACH, but a visit to Mars could bring you face-to-face with water. Images taken by Mars Global Surveyor suggest that liquid water shaped features on the martian surface in the recent past — and may still do so today. Although planetary scientists had seen tantalizing clues of water action (see "Red Planet Renaissance," July 2000), the new images provide the best evidence yet. This one reveals gullies eroded into the wall of an impact crater in the Noachis Terra region. The lack of small craters proves the gullies formed within the last few million years and suggests water may still flow. In the cold, dry, rarefied air of Mars, liquid water reaching the surface would instantly begin to boil, evaporate, and freeze — all at once — so it must have seeped from underground. *Astronomy* will report on the latest Mars news next month.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INTERSTELLAR MEDIUM

Fullerenes and Life's History

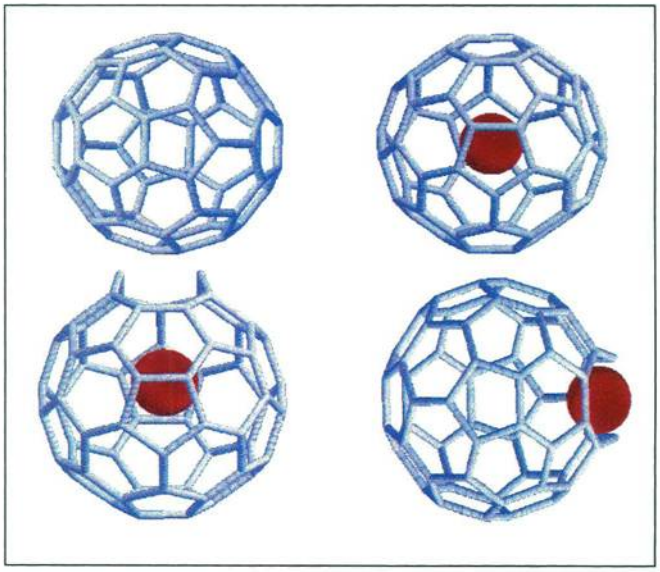
▶ Fullerenes have always been exotic, ever since the cagelike molecules of pure carbon were discovered, serendipitously, as a creation of high-temperature flame experiments.

Now some geochemists have evidence fullerenes may have played a significant role in the history of life on Earth. The hard carbon cages could have ferried in exotic gas molecules necessary for building Earth's atmosphere, thereby providing a rich environment in which the earliest, self-replicating molecules of life could form.

A team of scientists from the University of Hawaii, University of Rochester, and NASA have recovered argon, neon, and helium from inside fullerenes embedded in the 4.6 billion-year-old Allende and Murchison meteorites, which date to the solar system's origin. The ratios of the isotopes of the gases are different from the isotopic ratios of those gases found on Earth today. That shows, says Luann Becker of the University of Hawaii, the fullerenes could not have been created in the heat of impact, thereby trapping Earth gases.

"We've got fullerenes with exotic stuff inside," Becker says. "It tells us this stuff is out of this world."

Stanley Miller, a University of California, San Diego, research chemist and expert on the early Earth is not convinced the fullerenes played any significant role. "It's a good way to bring gases in," Miller said of fullerenes. "But I think it's a small amount. It's quirky."



An atom (red) trapped inside a cagelike fullerene escapes when one of the molecule's bonds breaks. Luann Becker (Univ. of Hawaii), et al.

Many planetary scientists believe cometary bombardments early in Earth's history brought in water, carbon, and other important substances. And, of course, some materials were available on the planet itself.

Becker doubts, however, that the exotic gases they found could arrive easily in comets.

Becker's team also has found more extraterrestrial fullerenes — in debris from the great dinosaur-killing impact 65 million years ago. The ubiquity of the pure carbon molecules leads her to reason that a steady rain of fullerenes through much of Earth's history could have contributed significant amounts of gas.

Although the source of the extraterrestrial fullerenes is not established, Becker suspects they were created in the hot interiors of stars. The team is now searching for other trace gases in fullerenes. — David Graham

GLOBULAR CLUSTERS

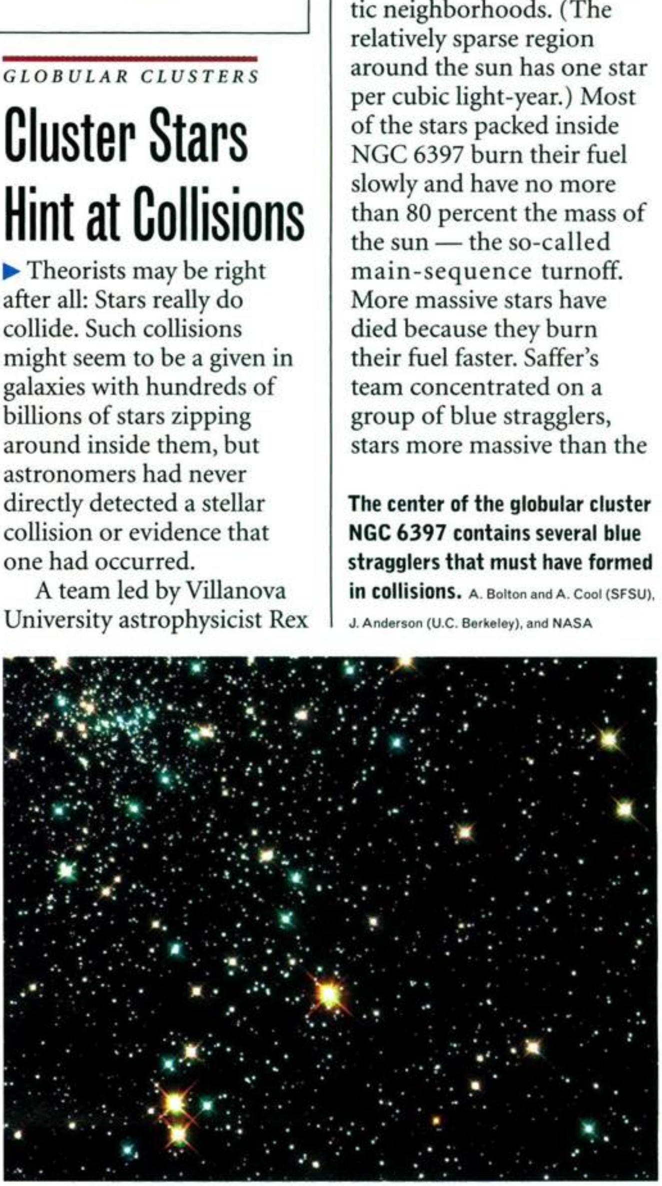
Cluster Stars Hint at Collisions

▶ Theorists may be right after all: Stars really do collide. Such collisions might seem to be a given in galaxies with hundreds of billions of stars zipping around inside them, but astronomers had never directly detected a stellar collision or evidence that one had occurred.

A team led by Villanova University astrophysicist Rex Saffer appears to be the first to find the smoking gun of such a stellar collision. Actually, the team found five smoking guns in the globular cluster NGC 6397, a spherical concentration of approximately 100,000 stars located 8,500 light-years from the sun in the southern constellation Ara.

Globular clusters are made up of stars almost as old as the universe itself and are much more compact — up to 1 million stars per cubic light-year at their cores — than typical galactic neighborhoods. (The relatively sparse region around the sun has one star per cubic light-year.) Most of the stars packed inside NGC 6397 burn their fuel slowly and have no more than 80 percent the mass of the sun — the so-called main-sequence turnoff. More massive stars have died because they burn their fuel faster. Saffer's team concentrated on a group of blue stragglers, stars more massive than the

The center of the globular cluster NGC 6397 contains several blue stragglers that must have formed in collisions. A. Bolton and A. Cool (SFSU), J. Anderson (U.C. Berkeley), and NASA



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Comet Hale-Bopp spent most of its life in the distant Oort Cloud, but it apparently formed closer to the planet Neptune. Leo Aerts

sun but only one-tenth the age of the cluster.

"These blue stragglers must have been produced after the other stars," says Saffer, who reported the analysis at the June meeting of the American Astronomical Society in Rochester, New York. Of the five blue stragglers his group analyzed, four have twice the mass of the cluster's main-sequence turnoff, a result consistent with the merger or collision of two stars. The fifth blue straggler had three times the mass of the main-sequence turnoff. "The mass of this star strongly suggests it was produced by collision," says Saffer. "This is the first direct evidence of the long-held theory that stellar collisions occur."

Michael Shara, an astrophysicist with the American Museum of Natural History who participated in the study along with astronomers at the European Space Agency, agrees that the five blue stragglers arose from collisions or mergers. "I'd call it 99 percent irrefutable," he says. — R. G.

COMET ORIGINS

Hale-Bopp's Birthplace

▶ Just three years ago, Comet Hale-Bopp gleamed spectacularly in Earth's evening sky. The brilliant comet had long ago been nudged out of its home in the distant Oort Cloud, a vast repository of possibly 1 trillion comets that were ejected long ago from the inner solar system.

However, Hale-Bopp's birthplace has remained a mystery. Many astronomers believed the comet — like many of the others found in the Oort Cloud — originally coalesced in the vicinity of Jupiter. Those who model the solar system agree that the massive planet gravitationally bulldozed the region clean not long after its formation.

S. Alan Stern, an astronomer with the Southwest Research Institute in Boulder, Colorado, has a different idea. He reported at the June meeting of the American Astronomical Society in Rochester, New York, that Hale-Bopp was loaded with a telltale gas — argon. Stern gathered this data from instruments aboard a sounding rocket launched from the White Sands Missile Range in New Mexico on the evening of March 29, 1997. Argon is a volatile gas that freezes only at temperatures 30° to 35° C above absolute zero.

Most theorists would not expect comets that formed in Jupiter's region to contain argon because that part of the solar system likely was too warm for the gas to freeze, says Stern. "Hale-Bopp couldn't have formed in the Jupiter region," he adds. "It probably formed in the Uranus-Neptune realm, or even farther out." — R. G.

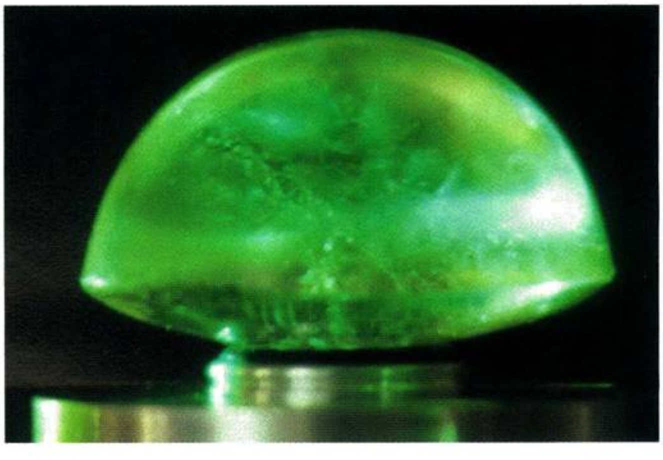
HISTORY OF ASTRONOMY

Viking Conquest of the Heavens?

▶ Vikings from the island of Gotland in the Baltic Sea could have used telescopes to gaze at the stars hundreds of years before the Dutch spectacle maker Hans Lippershey assembled his first telescope in 1608. Rock-crystal lenses with exceptional optical qualities have been discovered by archaeologists at digs in Gotland and nearby Fröjel. However, Olaf Schmidt of the University of Applied Science in Aalen, Germany, points out "There is a big

This rock-crystal lens hints that Vikings may have used telescopes centuries before other Europeans.

Olaf Schmidt and Bernd Lingelbach



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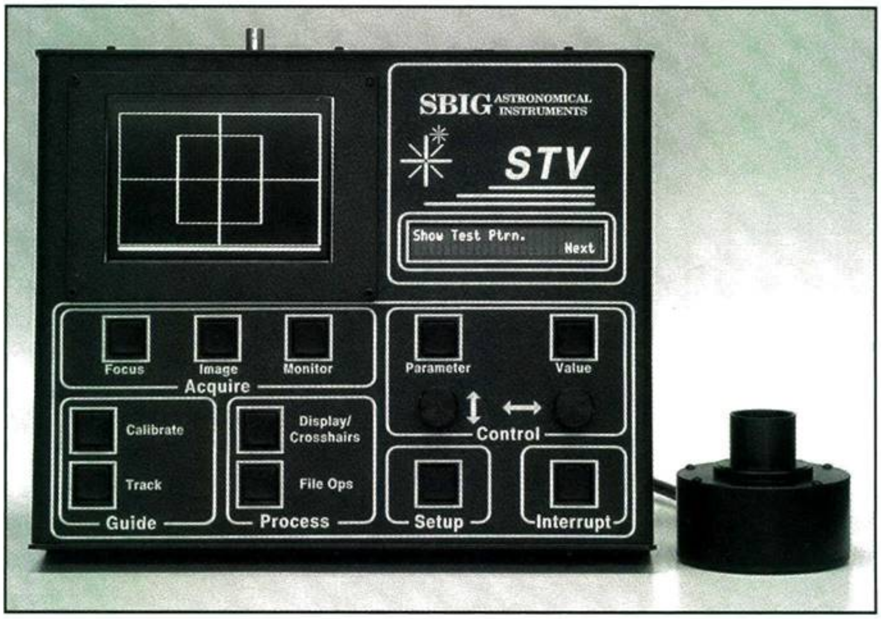
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difference in having the pieces and having the knowledge to put them together correctly."

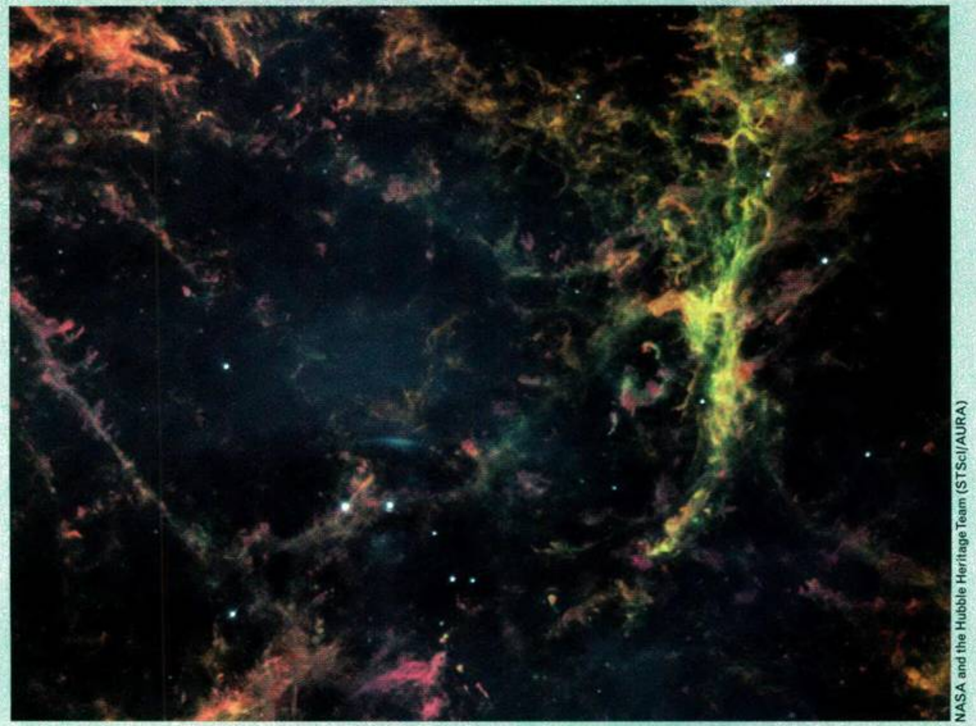
The intended use of these crystals is not certain. Some appear to have been made as purely ornamental objects with elaborate silver settings. Others are so nearly perfect in form that aberration curves are comparable to those used in eyeglasses today.

Dan Carlsson of Gotland University College in Visby, Sweden, has been conducting archaeological excavations in the Viking Age harbor at Fröjel and has found rock crystal cut into different shapes, including whole beads, half beads, and raw rock-crystal material. These various stages of craft lead him to believe the faceted beads were made on location and that if the knowledge were available for this type of work then lens making was also a possibility.

Carlsson says he has "put forward the idea of the beads being made at the site in Fröjel, mainly because we have a lot of raw material as well as half-finished beads. One bead was supposed to be some three centimeters across, and we can clearly see that they had started to drill the stone from both sides, before it cracked in two pieces. I can't say that they also made lenses on the spot, but I wouldn't be surprised if we also find half-finished lenses in our future excavations."

Previous theory held that Vikings did not have the technology available to make such items and that these sea travelers brought the lenses to Gotland from the ancient Byzantine Empire or elsewhere in Eastern Europe.

HUBBLE SPACE TELESCOPE



NASA and the Hubble Heritage Team (STScI/AURA)

DELICATE TENDRILS OF RARIFIED GAS lace the central regions of the Crab Nebula, a supernova remnant in Taurus. In July 1054, Chinese astronomers witnessed a "Guest Star" so bright that it could be seen in daylight. We now know this was a supernova, the death throes of a star that began its life with about 10 times the mass of the sun. Once the star had exhausted its fuel, its core collapsed, creating a shock wave that ripped the star apart. The core of that star survived the explosion and became a pulsar, which can be seen in this Hubble image as the right-hand component of the two moderately bright stars below and to the left of center. The network of colorful filaments is the gas that made up the outer layers of the exploding star, zipping along at more than 3 million miles per hour. The colors show different chemical elements in the expanding gas: hydrogen (orange), nitrogen (red), sulfur (pink), and oxygen (green). All these except the hydrogen were created during the evolution and explosion of the star.

Schmidt argues that the silver mountings aren't Viking style, which would suggest that they were imported. Also the age of the rock-crystal lenses predates the first appearance of rock crystal on Gotland. Experts on rock crystal came from areas around Persia and the Black Sea, which would point to Byzantium as the source. Gotlandic soldiers often ranged into Byzantium as well and likely brought precious goods back with them.

Still another theory has been put forth by Giovanni Pettinato of the University of Rome, who cites another rock-crystal lens as proof that as far back as 2,500 years before Lippershey, the ancient Assyrians were gathering information about the planets in general and Saturn in particular. Pettinato asserts that the Nimrud lens, which was found in 1850 by Sir John Layard at the palace of Nimrud in modern Iraq, was used by Assyrian astronomers to study the planets. The Assyrians believed the planets were deities and depicted Saturn as a god surrounded by rings of snakes.

Throughout history humans have looked to the sky for answers. Perhaps they had a better view than we ever imagined.
— Kristin Kizer

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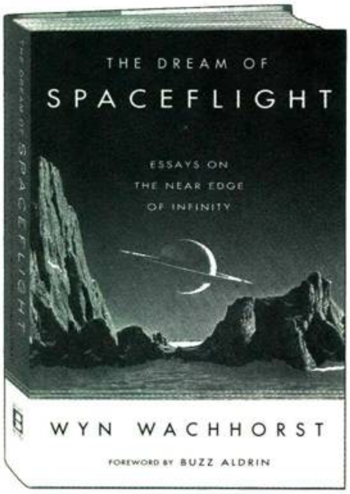
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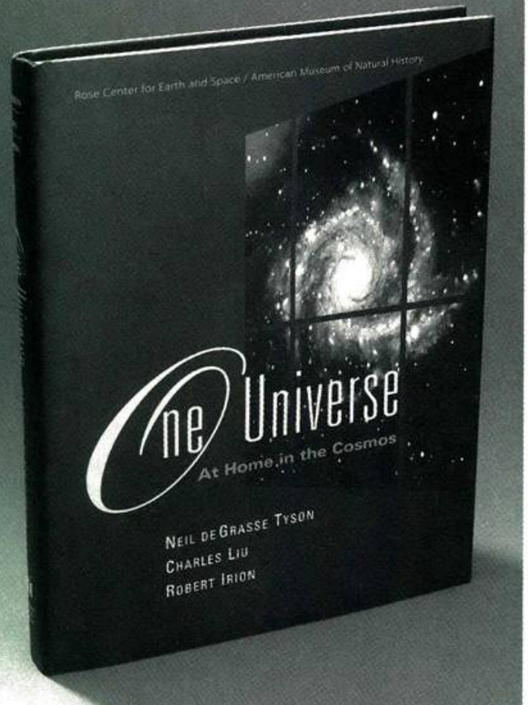
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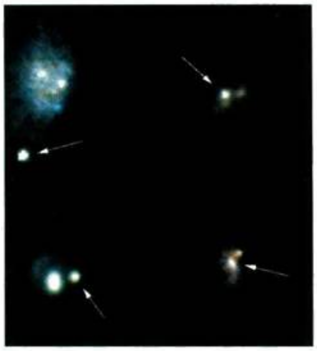

Astronomers are using distant supernovae (arrows) to measure the cosmos. High-z Supernova Search Team

COSMOLOGY

The Universe on Speed

▶ About a year ago, two independent research teams made compelling cases that the universe will expand forever at an ever-increasing rate. The evidence for an accelerating universe is based on the measurements of the most distant Type Ia supernovae. These supernovae are about 25 percent dimmer than would be expected if the expansion rate was not accelerating.

However, this conclusion relies on the assumption that supernovae in the distant past behave the same as those today. Many astronomers are skeptical of this assumption, pointing out that the stars that exploded in the past formed from a different chemical mix of gases than those exploding now. In the last six months, supernova researchers have weighed in with further evidence that the older the universe gets, the faster it expands.

Current models predict that the time between a supernova's explosion and its maximum brightness should change if supernovae really do evolve. Adam Riess and his colleagues from the High-z Supernova Search Team reported in the December 1999 *Astronomical Journal* just such a change. They compared the rise times of nearby supernovae (those with low redshifts) with the preliminary analysis of the rise times of very distant (high-redshift) supernovae. They found that the distant supernovae took about 2.5 days less to reach maximum brightness than those with low redshifts. The team decided that supernovae may well evolve and suggested that this might potentially alter the accelerating universe conclusion.

Recently, however, members of the Supernova Cosmology Project completed their analysis of the rise times of high-redshift supernovae. Greg Aldering, Robert Knop, and Peter Nugent report in an upcoming issue of the *Astronomical Journal* that no compelling evidence exists for a difference in rise times between nearby and distant supernovae and therefore no evidence that supernovae evolve.

What does all this mean?

"The most likely conclusion is that the universe is accelerating," says Riess, "though we persist in our attempt to be our own harshest critics and search for other possibilities." Saul Perlmutter, who heads the Supernova Cosmology Project, agrees. "I do think that it is still important to keep hunting for new, unaccounted-for differences between supernovae in different environments, such as would be expected as you look to higher and higher redshifts." — Jennifer Birriel

Mars Revealed in a Virtual Gallery

What would you do with 20,000 photos of your favorite place? Scientists working with the Mars Global Surveyor spacecraft recently found themselves in just that position and decided to create a web-based photo album, allowing anyone with Internet access to browse through the treasure trove of images. This marks the largest one-time release of images for any planet in the history of solar system exploration. The archive covers a single martian year (687 Earth days) from September 1997 to August 1999. Many of the images resolve objects on the surface the size of a school bus. "People can experience the pictures the same way scientists do," says Ken Edgett of Malin Space Science Systems, "one at a time, no captions or explanations, just 'Here it is. What does it show me?'" You can find the archive at http://www.msss.com/moc_gallery/.

Afternoon clouds cling to the slopes of Mars's Tharsis volcanoes. NASA/JPL/MSSS

Compton's Demise a Success

June 4 was a bittersweet day for NASA and astronomers around the world. After nine remarkable years of discovery, the Compton Gamma Ray Observatory reentered Earth's atmosphere at 2:10 A.M. EDT. Although most of the 17-ton observatory burned up during reentry, a few dozen fragments presumably survived, littering the Pacific Ocean about 2,400 miles southeast of Hawaii. NASA decided to bring Compton down after one of its three gyroscopes failed last December (see "Compton at the End of the Road," AstroNews, July 2000). Although still working perfectly well, the spacecraft posed a threat: If it had lost another gyro, it could have reentered the atmosphere out of control and threatened a populated area.

The Universe Develops a Sweet Tooth

Astronomers have just discovered sugar — in space, that is. Using a 12-meter radio telescope on Kitt Peak in Arizona, Jan Hollis of NASA's Goddard Space Flight Center, Frank Lovas of the University of Illinois, and Philip Jewell of the National Radio Astronomy Observatory detected glycolaldehyde in an interstellar cloud near the center of our galaxy. This 8-atom molecule can combine with other molecules to form more-complex sugars. "The discovery of this sugar molecule in a star-forming cloud means it is increasingly likely that the chemical precursors to life are formed in such clouds long before planets develop," says Hollis.

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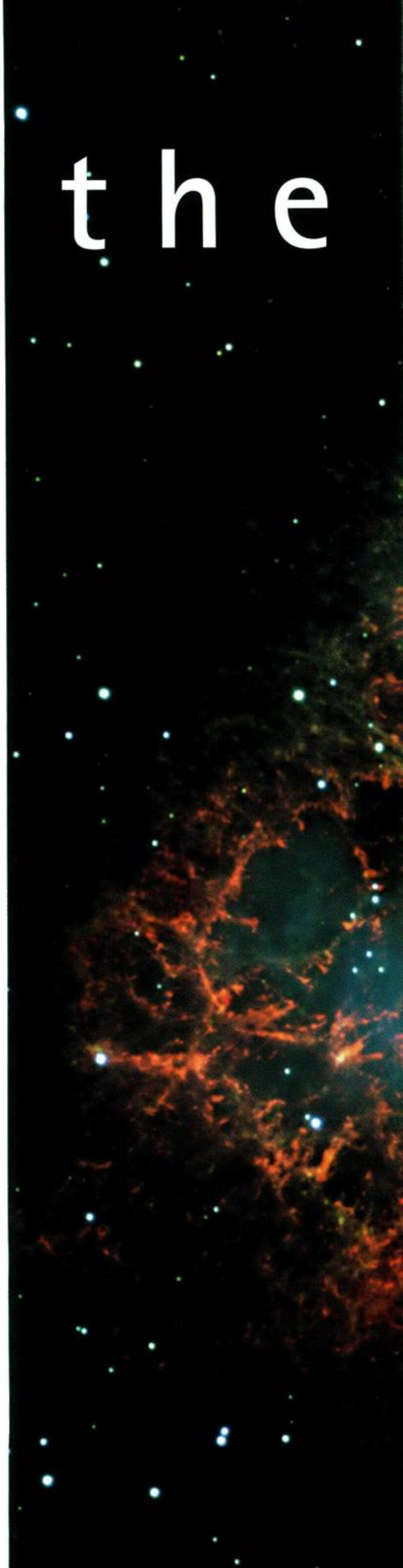
Beyond the

Astronomers have opened new windows on the universe by studying the kinds of "light" we can't see with our eyes.

by James B. Kaler



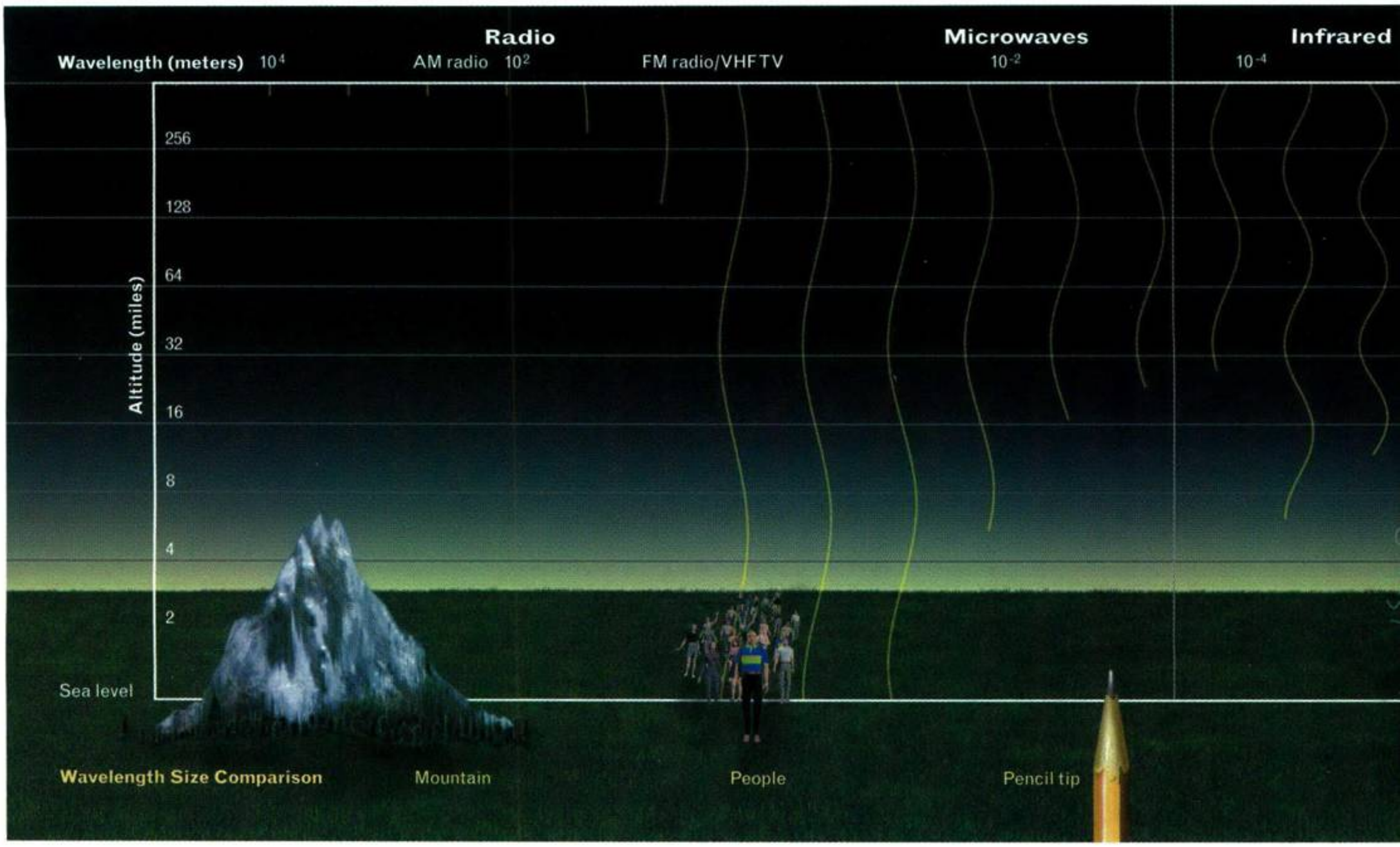
It's everywhere around you. It pervades Earth, the sky, the universe, and is bouncing off and passing through you at this very moment. It can be highly destructive yet is utterly necessary for life. For astronomers, it's by far the most important way of unlocking the secrets of the cosmos.

We know it best as light. But the light we see with our eyes is just a tiny sliver of a vast electromagnetic spectrum produced by everything from comets to quasars. We can understand little about the universe without an understanding and appreciation of visible light and its invisible partners in the electromagnetic spectrum: radio waves, infrared light, ultraviolet light, x rays, and gamma rays. All these different forms of light are fundamentally the same thing.

Scientists now know that light can be described as a train of waves that carries energy. These waves are in fact the universe's principal means for transmitting energy. Unlike water and sound waves, however, light does not need a substance through which to travel. Instead, it consists of waves of alternating electric and magnetic fields that move through a vacuum at the cosmic speed limit of 186,000 miles (300,000 kilometers) per second. The different kinds of light are waves that have different lengths between consecutive crests or troughs.

Europe's Very Large Telescope captures the Crab Nebula in visible light. ESO

Rainbow



Energy Carriers

Visible light and its cousins are not equal-opportunity carriers of energy. Besides being viewed as waves, light can also be viewed as consisting of massless particles known as photons. The shorter the wavelength, the higher the energy of a photon. X rays, whose wavelengths are shorter than a virus, have such high energy that they can penetrate the human body. This allows physicians to use x rays for medical tests. But overexposure to x rays can damage the body's cells, causing cancer.

Gamma rays, which are released in atomic-bomb blasts, have even shorter wavelengths — the size of atoms. Gamma-ray photons carry more energy than x-ray photons, and are thus even deadlier. We do not yet know the energy limit that gamma rays may have. The wavelength limits of the electromagnetic spectrum remain unknown.

The various colors of visible light have wavelengths somewhat less than a thousandth of a millimeter, about the size of bacteria. Visible light packs enough energy to stimulate chemical reactions in your eye, allowing you to see.

Ultraviolet light, which has wavelengths shorter than visible light but longer than x rays, begins to carry enough energy to be dangerous. Solar ultraviolet light causes sunburn at the same time the sun's infrared light tempts us to go outdoors.

Infrared light, which is also known as infrared radiation (when referring to the electromagnetic spectrum, scientists often use "light" and "radiation" interchangeably), falls between visible and radio. If you place your hand next to your cheek, you can feel infrared light as heat pouring from your skin.

Waves longer than about a millimeter belong in the radio spectrum, which extends to mountain-sized waves many miles long. Because they have such long wavelengths, radio waves do not carry much energy and are thus not particularly harmful, as evidenced by the good health of those who live or work next to megawatt radio transmitters. Only at certain shorter radio wavelengths (called microwaves), where the waves are vigorously absorbed by water, can they be dangerous.

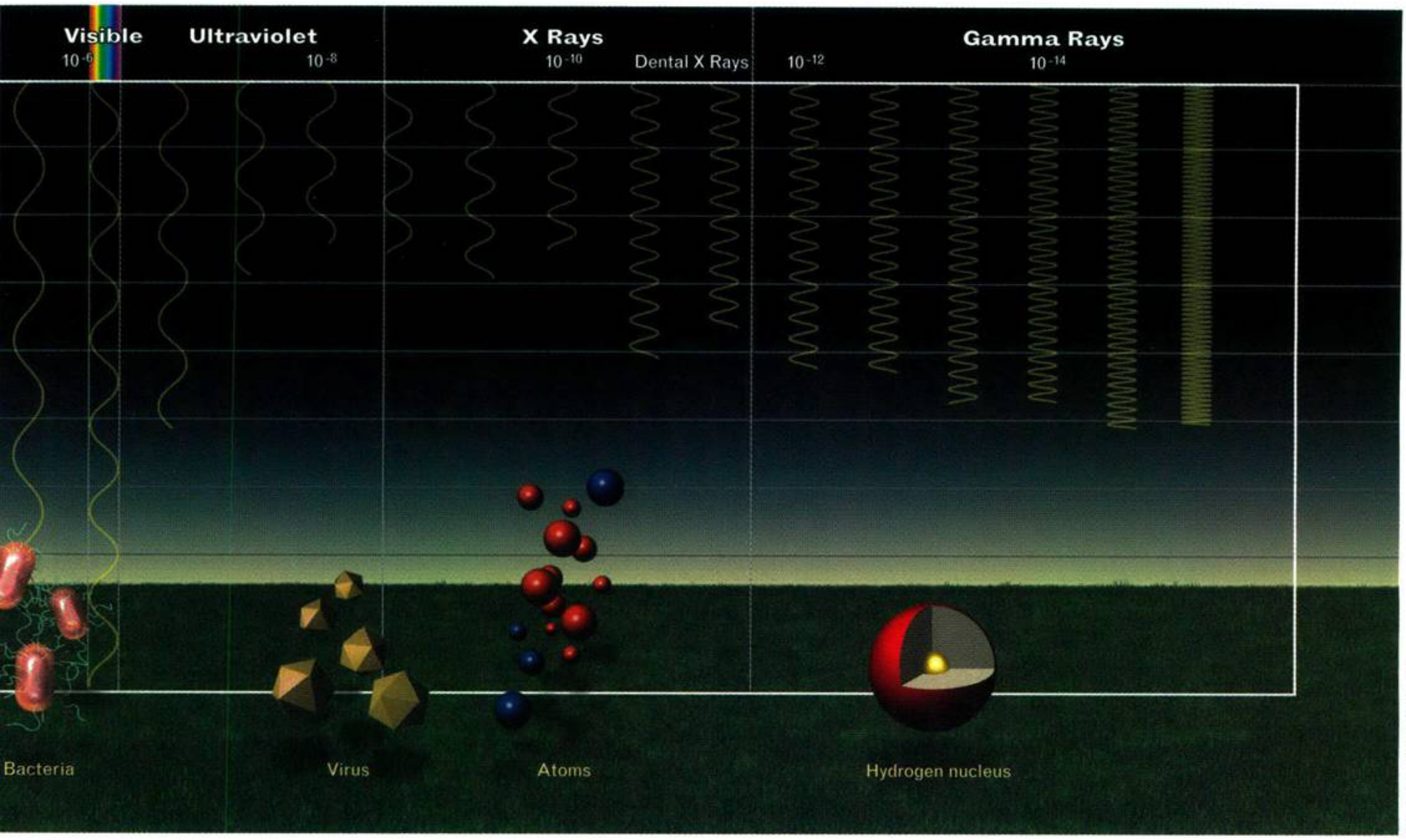
Kaleidoscope of Colors

In 1666, Isaac Newton took the first step toward understanding visible light when he passed sunlight through a prism and watched it separate into a kaleidoscope of colors. Just like the wavelength differences between various parts of the electromagnetic spectrum, the variety of colors comprising visible light are made of waves that have different lengths between successive crests or troughs. Red waves are the longest, violet the shortest.

William Herschel, the discoverer of Uranus, was the first to explore the region beyond the rainbow of visible light. In 1800, he reported on experiments to determine the heating power of different colors, in which he let a spectrum of light fall on a set of thermometers. To his surprise, he found that the greatest heat was produced off the red end of the spectrum where nothing was visible. "Radiant heat," he proclaimed, "will at least partly consist, if I may be permitted the expression, of invisible light." Herschel had discovered infrared radiation.

In the mid-19th century, astrophotographers began to explore the other end of the spectrum. Photographic emulsions are particularly sensitive to shorter wavelengths of light, blue and violet. Astronomers discovered that stars and nebulae radiate beyond violet light, hence the term "ultraviolet."

Physicists completed the picture in the late 19th and early 20th centuries with the discovery of radio waves, ultraviolet light, x rays, and gamma rays. Astronomers came to realize that



Visible light makes up just a small portion of the electromagnetic spectrum. Gamma rays have wavelengths the size of an atomic nucleus, while the longest radio waves are the size of mountains. The atmosphere allows some radio wavelengths and visible light to penetrate all the way to sea level, but it absorbs or blocks light at other wavelengths.

Astronomy: Elisabeth Rowan

many astronomical bodies radiate little or no visible light at all and remain hidden without full spectral exploration. Trying to understand the universe through visible light alone is like listening to a Beethoven symphony and hearing only the cellos. Only by studying images and spectra taken across the entire electromagnetic spectrum can astronomers appreciate the full scope of the universe.

In the 1930s, Karl Jansky, an engineer for Bell Labs, took the first step in opening up the entire electromagnetic spectrum when he discovered radio waves from deep space using a simple antenna. Radar technology developed during World War II eventually led to the radio telescopes of today. Radio telescopes "hear" nothing. Their mission is to map where radio waves are coming from so astronomers can learn about the radiating bodies' physical conditions. The way in which radio telescopes work is similar to optical (visible light) telescopes. They have large, curved collecting surfaces that reflect incoming radio photons to amplifiers and receivers.

Radiation Double Talk

The term "radiation" has a confusing dual meaning. In the early days of the study of radioactive elements, scientists discriminated among alpha rays, beta rays, and gamma rays. Alpha rays turned out to be high-speed helium atoms (helium nuclei are still commonly called "alpha particles"); beta rays were electrons. As a result, we must distinguish between "particle radiation," which now means a flow of any high-speed energetic particles, and "electromagnetic radiation," which includes all the forms of light, including radio waves, visible light, and gamma rays.

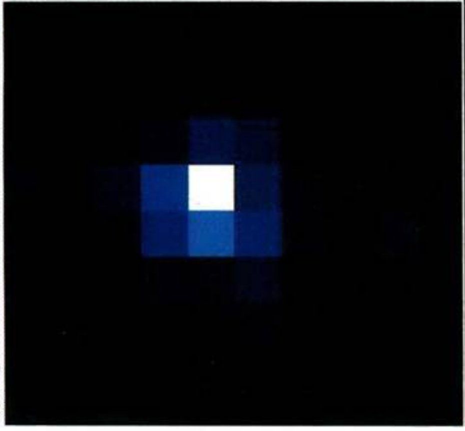
Because radio waves have long wavelengths, they are not good at resolving small structures. To maximize resolution, astronomers build very large radio telescopes up to 1,000 feet (300 meters) across. Still, these telescopes have about the resolution of the human eye. Astronomers electronically coordinate individual radio telescopes hundreds of miles apart or synchronize their observations with clocks to construct "virtual" telescopes of continental size. Such radio interferometers can resolve details far sharper than anything current optical telescopes can see.

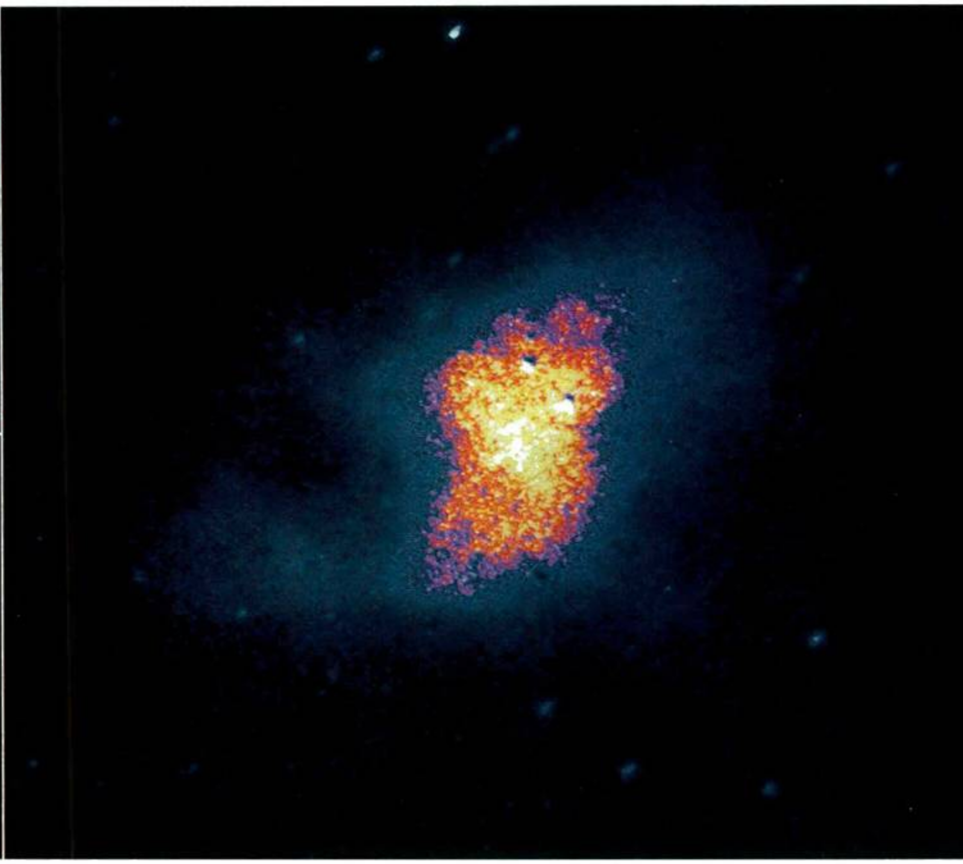
After developing radio astronomy in the mid-20th century, astronomers turned their attention to the rest of the electromagnetic spectrum. After languishing since the days of Herschel, the field of infrared astronomy has come alive in the last 20 years with the advent of good detectors that can be fitted to optical telescopes. More recently, astronomers bridged the gap between radio and infrared — millimeter waves and microwaves — and have now mastered the entire long-wave realm of the spectrum. Herschel would be proud.

A Blessing and a Curse

Astronomers had to wait until the Space Age before they could open up the short-wave realm of the electromagnetic spectrum. That's because Earth's atmosphere absorbs almost all high-energy radiation. While this might sound like bad news for astronomers, it's actually good for all living things.

The atmosphere blocks radiation just to the short-wave side of violet light, allowing only a little bit of ultraviolet to sneak through. This protects





Upper Right: Caltech/IPAC/University of Massachusetts; Lower Right: EGRET Team and NASA; Far Right: UIT Team/NASA/GSFC

us from harmful ultraviolet light and x rays from solar magnetic storms. Much of the ultraviolet is blocked by ozone high in the stratosphere. Without this ozone layer, living on Earth's surface would be hazardous to one's health.

So what can astronomers do if they want to observe the kinds of light that are absorbed by the atmosphere? High mountaintops and dry south polar air are a help, but they do not really get to the root of the problem. The only recourse is to go into space.

Following a series of rocket experiments in the 1960s, Uhuru, the Einstein Observatory, ROSAT (Röntgen Satellite, after the discoverer of x rays), and now the Chandra X-ray Observatory have examined the x-ray region. Astronomers have used these satellites to map hot gas in galaxy clusters, explore the nature of expanding clouds from exploded stars, and examine the impact of the solar wind on comets.

The Compton Gamma Ray Observatory, which fell back to Earth last June, and other gamma-ray satellites have explored the highest-energy part of the spectrum. They have been hit about once a day with the mysterious gamma-ray bursts from deep space.

The International Ultraviolet Explorer (IUE) was launched in 1976. Designed to last for three years, it was recently decommissioned after an amazing 20 years of service, a testimony to superb engineering. IUE and other ultraviolet satellites have revealed clusters of hot, newborn stars in distant galaxies, among other things.

While a few infrared bands make it to the surface, carbon dioxide and water vapor in the atmosphere absorb most infrared light before it reaches the ground. Infrared astronomers will go to almost any length to limit the water vapor over their heads, including putting telescopes in airplanes and establishing observatories in the bitter cold of the South Pole, which is one of the driest places on Earth.

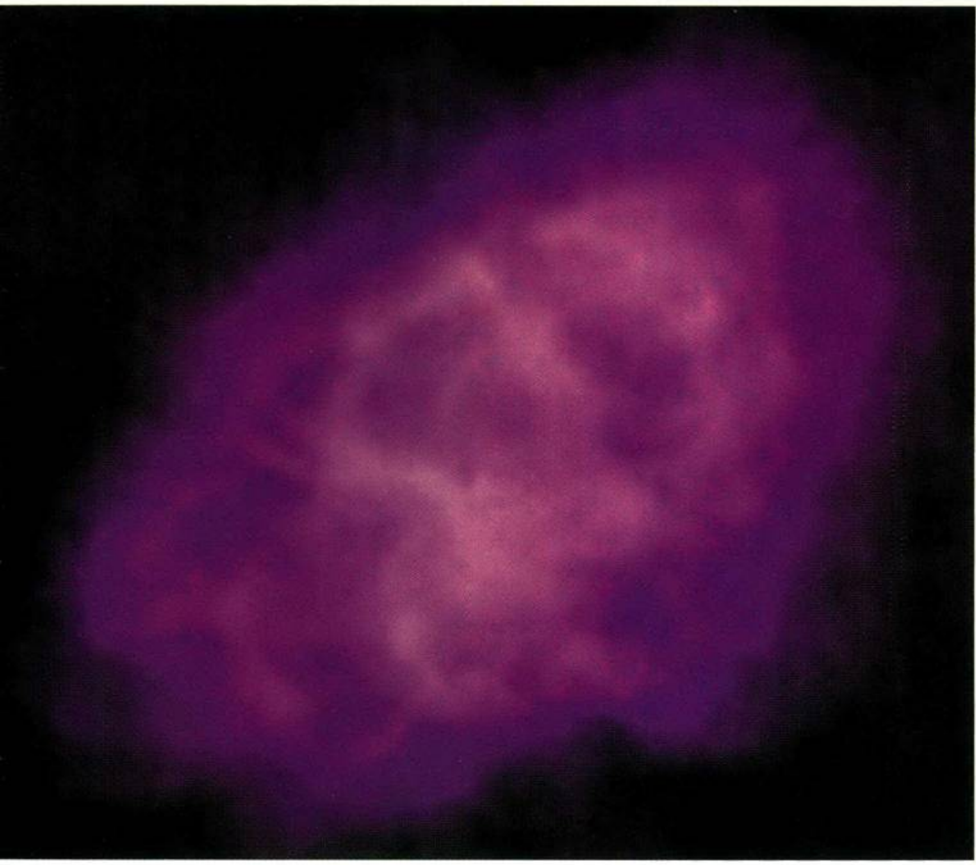
In 1983, the Infrared Astronomical Satellite (IRAS) mapped the sky in four infrared bands. IRAS collected so much data that an institute dedicated to the satellite is still doing business at the California Institute of Technology. The Infrared Space Observatory (ISO) followed, and late next year the Space Infrared Telescope Facility (SIRTF) will greatly extend astronomers' knowledge of the infrared universe.

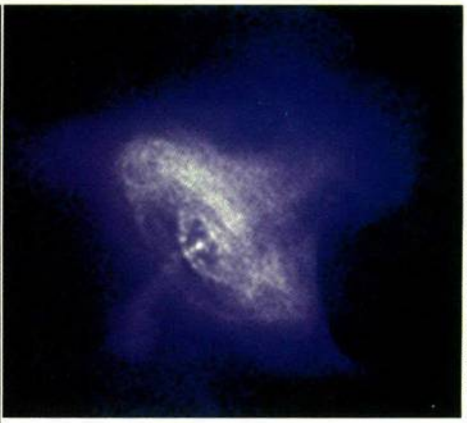
Even though many radio wavelengths can reach Earth's surface, astronomers still launch radio telescopes into space. A Japanese space radio telescope, HALCA, works with radio telescopes on the ground to form an interferometer twice as big as Earth.

Hubble is the king of space telescopes. It is the only one that has general visible-light capability, allowing it to produce images that we can recognize but with a wonderful difference. All visible light wavelengths make it to the surface on a clear night, but Earth's atmosphere causes stars to twinkle, which degrades images made of celestial bodies. From above the atmosphere, the stars stare serenely down at us, allowing Hubble to see the heavens with 10 times the detail that is generally achieved from Earth's surface. Hubble can also observe well into the ultraviolet and infrared.

The Temperature Connection

Light is produced when atoms release stored energy. In the simplest case, the kinds of electromagnetic radiation that a body emits depend on its temperature, which is a measure of its internal energy. Measurements of different kinds of waves thus allow astronomers to determine temperature. In addition, from the way that electromagnetic radiation interacts with matter, astronomers can determine chemical compositions, velocities, and





Far left: NRAO; Left: NASA/CXC/SAO

The Crab Nebula (M1) assumes different appearances depending on wavelength. At the far upper left, the 2MASS survey captures the Crab at infrared wavelengths. Below that is a picture from the Compton Gamma-Ray Observatory (gamma-ray instruments have extremely poor resolution). To the right of those images is an ultraviolet image taken from the ASTRO satellite. On this page, the large image was taken at radio wavelengths by the Very Large Array. Above, Chandra images x-ray emission from the central region of the Crab Nebula. Each image shows different characteristics of this supernova remnant.

other physical properties of objects that range from icy cold to scorching hot.

Cold objects such as interstellar clouds of gas and dust don't have enough energy to radiate x rays or even visible light. The enormous rift that divides the Milky Way in two consists of thick dust that visible light cannot penetrate. Because the dust blocks starlight, the clouds are chilled to only a few degrees above absolute zero and radiate best at radio and long infrared wavelengths. Molecules form within these clouds, where the dust protects them against the ravages of stellar radiation.

Just as you can hear a radio on a foggy day in which you can barely see the car in front of you, radio and infrared waves can punch through interstellar dust, allowing astronomers to probe within the dark clouds and see clearly across our galaxy. Until astronomers examined the clouds with sensitive radio telescopes in the early 1960s, they had almost no hint of the huge variety of molecules that exist in space and lacked knowledge of the most massive units of the galaxy, giant molecular clouds. The low temperatures allow the gas to contract gravitationally to form stars, so without radio and infrared astronomy, there would be no way to observe how stars are born.

As a body's temperature increases, it can radiate at higher energies. At a few hundred degrees above absolute zero, objects radiate strongly in the shorter wave infrared. That's why an infrared camera can take your picture at night. Astronomers use infrared light to study the advanced stages of star formation and warm dust ejected by dying stars.

At a few thousand degrees, a body produces visible and even some ultraviolet light (in addition to infrared and radio). The surface temperatures of most stars lie between 3500° F and 90,000° F (2000° C and 50,000° C) and are, like the heated filaments of light bulbs, powerful emitters in the visible. Cool stars radiate most of their energy in the infrared. Hot stars radiate mostly in the ultraviolet, so without examination of these spectral bands, astronomers would lack a great deal of important information.

Now boost the temperature to 1 million degrees F (about half a million degrees C) and out pour x rays, and at higher temperatures yet, gamma rays. Thermonuclear reactions at the center of the sun, at 27 million degrees F (15 million degrees C), produce gamma rays that are reduced in energy by their passage through the cooler solar envelope. What begins as a single gamma ray photon in the sun's core emerges at the surface as thousands of visible-light photons. Our sun appears relatively quiescent when viewed in visible light. But an examination in x rays reveals spectacular loops of gas heated to millions of degrees by solar magnetism. Without this knowledge, astronomers can make no sense of the solar wind, solar activity, and their effects on Earth.

X rays and gamma rays also originate from exploded stars. X rays are produced in enormously hot gas that lies within clusters of galaxies and by matter falling into black holes. Gamma rays seem to burst forth from collapsing supermassive stars (or even colliding neutron stars) in distant galaxies.

Our century has seen the entire electromagnetic spectrum opened for business. With new detectors, new satellites, and imaginative plans for future exploration, astronomical objects will yield up their various secrets at an ever-accelerating pace, allowing a fuller understanding of our universe.

James B. Kaler studies stellar evolution at the University of Illinois. He is the author of many books, the most recent of which is Cosmic Clouds. *He describes a different star each week at www.astro.uiuc.edu/~kaler/sow/sow.html.*

INTERVIEW WITH AN

ASTRONOMY: Do you keep up with the latest developments in the science of astronomy?

RUSS: I like to keep track of what's going on, absolutely. I'm a member of the Planetary Society here in Los Angeles. Plus, a friend of mine who's an astrophysicist is always calling me about what is going on.

ASTRONOMY: Is there anything you're particularly interested in — such as planetary exploration, black holes, cosmology?

RUSS: Anything and everything — the entire gamut from asteroids to black holes. My greatest interest is keeping track of current astronomical events and actually witnessing them, whether a collision on Jupiter or a supernova or something like that. That's the most exciting.

ASTRONOMY: Do you own a telescope and go out observing?

RUSS: I have five of them, actually — a 5-inch Maksutov, an 85mm refractor, a 10-inch Dobsonian, and an 8-inch Schmidt-Cassegrain. I also have a little ETX 92. Right now, each one has a specific function.

ASTRONOMY: When did you become interested in astronomy?

RUSS: I've had a casual interest in natural sciences, astronomy, and space exploration since high school and college. My hands-on hobby experience with astronomy started about 10 years ago, when I started going out and exploring and buying equipment.

ASTRONOMY: Have you ever done any astrophotography?

RUSS: I have done a little bit of astrophotography with a motor-driven telescope. Piggyback a camera, put a 100mm or 200mm lens on it and just shoot. Shoot something like Cygnus, the Veil Nebula, or the North America Nebula using 10-, 12-, or 13-minute exposures with high-speed film. It was very easy and I've had pretty good results.

ASTRONOMY: What's your favorite object?

RUSS: I do like large globular clusters — they're usually pretty spectacular.

ASTRONOMY: Like M13, M15 . . .

RUSS: . . . and M92. A few others are really dynamite, the summer objects primarily. Some of the nebulae and a couple of the galaxies are also interesting. But the clusters are really quite nice — globulars and some open clusters.

ASTRONOMY: Do you look at planets and the moon, too?

RUSS: All the time. I can just go out on my balcony and look at those things. As a matter of fact, I prefer to use my 85mm refractor. It has a binocular viewer on it and with that thing, the viewing is fantastic.

ASTRONOMY: Where do you like to do most of your viewing?

RUSS: Most is done just outside of Los Angeles, in the valley off Templin Highway. It's about a 40-minute drive to relatively dark skies. You can see the Milky Way visually, so that's at least dark enough to see most of the objects that I'm looking for. That I can do on a weeknight without having to stay overnight somewhere.

ASTRONOMY: Do other members of the *Voyager* cast observe with you?

RUSS: Sometimes I'll bring my telescopes to the set and we look at stuff while we're working, usually the moon and planets. That's it. One other crew member on the *Voyager* cast has a telescope. Roxanne Dawson (B'Elanna) sets it up in her backyard and looks at the moon occasionally. I'm the one who has a lot of equipment and will take the trouble to go out on a winter night. There are not very many people who want to do that.

ASTRONOMY: Especially in winter.

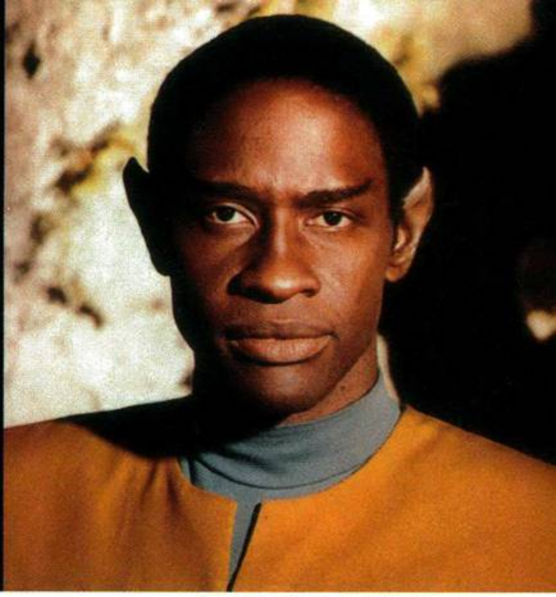
RUSS: When it gets that cold, it's just not practical. I think my Dobsonian is one of the best telescopes to use for that purpose. When it's cold as hell, I can go out, put the base down, put the tube in, put the eyepiece in and start rockin' and rollin'. Even before the mirror is cooled down I can look at things. The Dobs are designed to look straight up and down at zenith, with relative ease. That makes a big difference.

ASTRONOMY: Do you use the Dob for deep-sky observing?

RUSS: For the deep-sky stuff, I start with the Dob or the 8-inch SCT. And I'll sometimes use the 85mm short tube. Because it's a refractor, being as crisp

ALIEN

Although Tim Russ plays an alien on Star Trek Voyager*, his interest in astronomy is no act.*



Copyright © 1999 Paramount Pictures

and clear and sharp as it is, I see quite a bit through that little telescope. I'm very impressed with it. Then again, some of the open clusters and other things are unbelievably spectacular just through the binocular viewer.

ASTRONOMY: Your interest in astronomy predated your involvement in *Star Trek*. Does your role as a space-traveling alien hold any special irony for you?

RUSS: No, I view it merely as a coincidence. It literally could have been any series. It could have been *Baywatch*, for crying out loud. It was just one in a series of many auditions.

ASTRONOMY: Do you think science-fiction shows have a responsibility to portray science accurately?

RUSS: *Voyager*'s main objective is to tell a story — that's the business. The show has a couple of technical consultants. The writers and producers will ask, "Here's what we want to do, what are the basic theories that we can loosely base this story line on?" On occasion they'll contradict themselves. The science is all very loosely based on physics, but it's not a priority.

ASTRONOMY: You don't think it necessarily should be — that the main thing is to tell an entertaining story?

RUSS: Yes, in this case, it is a science-fiction show, not a science fact show. It is make-believe and therefore the latitude of all these things is pretty wide open. Even though a lot of the technology we discuss is actually being applied in some areas of science, it's still — as far as all the particulars of alien technology — only a guess as to what our technology will be 400 years from now. What we've done on *Star Trek* is to reduce the galaxy to the planet Earth. That's more or less the setup, the sort of microcosm that we display in the show. Everybody we run into is basically like us with an understanding of common technologies. Our viewers are suspending belief considerably for us to just tell that much of a story.

ASTRONOMY: Do you think that science fiction writers do a good job of depicting extraterrestrial life?

RUSS: It's entirely up to speculation and imagination. And it's hard to tell a story when you cannot communicate. We've had some really gnarly computer-generated imaging (CGI) creatures bouncing around and being really horrible. Generally, what we deal with is more of a cultural, political difference in these creatures. The physical difference only indicates that they are an alien race. The aliens on our show are designed to be functional and practical within a story-telling realm. If a story involves an alien race composed of gas or something in a jar and we can tell a decent story that way, then it's possible. But, a gaseous character is only interesting if it can move around — because you can't have a bottle on a table and talk to it for an hour.

ASTRONOMY: Do you think that *Star Trek* is optimistic about the number of intelligent civilizations in space?

RUSS: You know, given the Drake equation, I think that there is definitely a possibility. It's a very tough question. The problem comes from assuming that advanced technologies are going to be parallel. Who knows?

ASTRONOMY: You obviously support SETI as a member of the Planetary Society. Do you think SETI is our best way of trying to make contact or do you think maybe some of these civilizations might develop interstellar travel?

RUSS: I think the possibility exists that if somebody out there has unlocked the key to doing it, they would probably take the opportunity to do so. Who knows what the chances are of them finding us in the middle of nowhere? It's complicated.

ASTRONOMY: Astronomy involves profound thoughts and questions. Is that why dabbling in the hobby of astronomy appeals to you?

RUSS: Absolutely. When you're out there under a pitch-black sky, you look up at a cluster of stars and wonder. First of all, there's a sense of distance, a sense of size, and you realize just what a small part of this whole picture we are. That's what makes it interesting — the idea that you're looking at a galaxy and wondering if maybe somebody in that galaxy is looking back at you at exactly the same time and wondering the same thoughts. Plus, some of these objects are just pure and simply beautiful to look at.

For a complete transcript of this interview, please visit *Astronomy*'s website at www.astronomy.com.

Telescopes for the 21st Century

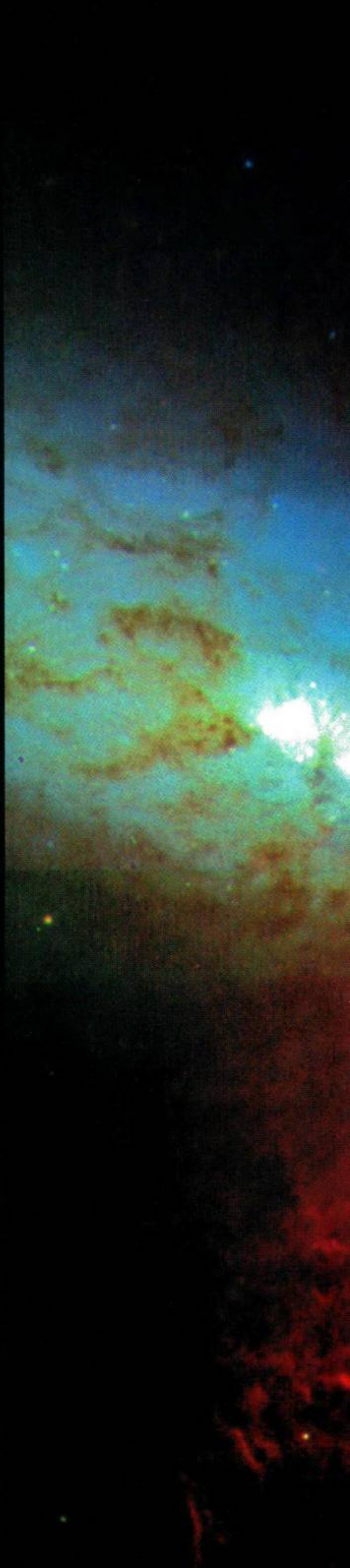
Probing Cosmic Depths

The world's largest single telescope mirror puts Japan at the forefront of optical astronomy.

by Ray Jayawardhana

The famous Keck twins, sitting pretty atop the summit of Mauna Kea on the Big Island of Hawaii, have a new neighbor. Subaru, named after the Pleiades star cluster (not the car company), is the prized possession of the National Astronomical Observatory of Japan. Unlike the Keck telescopes, whose 10-meter (33-foot) primary mirrors are each composed of 36 separate segments, Subaru uses one enormous 8.3-meter (27-foot) mirror to gather light from the cosmos. In fact, it is the world's largest single-mirror telescope.

Built at a cost of some 370 million U.S. dollars, Subaru helps Japan leapfrog to the forefront of optical and infrared astronomy. The telescope saw first light in January 1999 and will be offered partially for scientific observations later this year.



The galaxy M82 features countless hot blue stars and a superwind that ejects reddish hydrogen gas. All photos: © Subaru Telescope, National Astronomical Observatory of Japan

Subaru's "dome" stands out against those of the other telescopes on Mauna Kea because of its unusual shape: It's not a dome at all. Instead, the telescope building is cylindrical — a design based on wind-tunnel tests and computer simulations — to suppress local atmospheric turbulence. Twenty remote-controlled ventilators around the building provide additional help to improve the air flow above the primary.

The unique dome design is just one of many novel features that makes Subaru perhaps the most high-tech telescope on the ground. Others include an active support system that maintains the mirror shape to high precision, a tracking mechanism that achieves extreme accuracy by using magnetic drives, seven observational instruments installed at four foci, and two "auto-exchanger" systems for switching instruments and secondary mirrors.

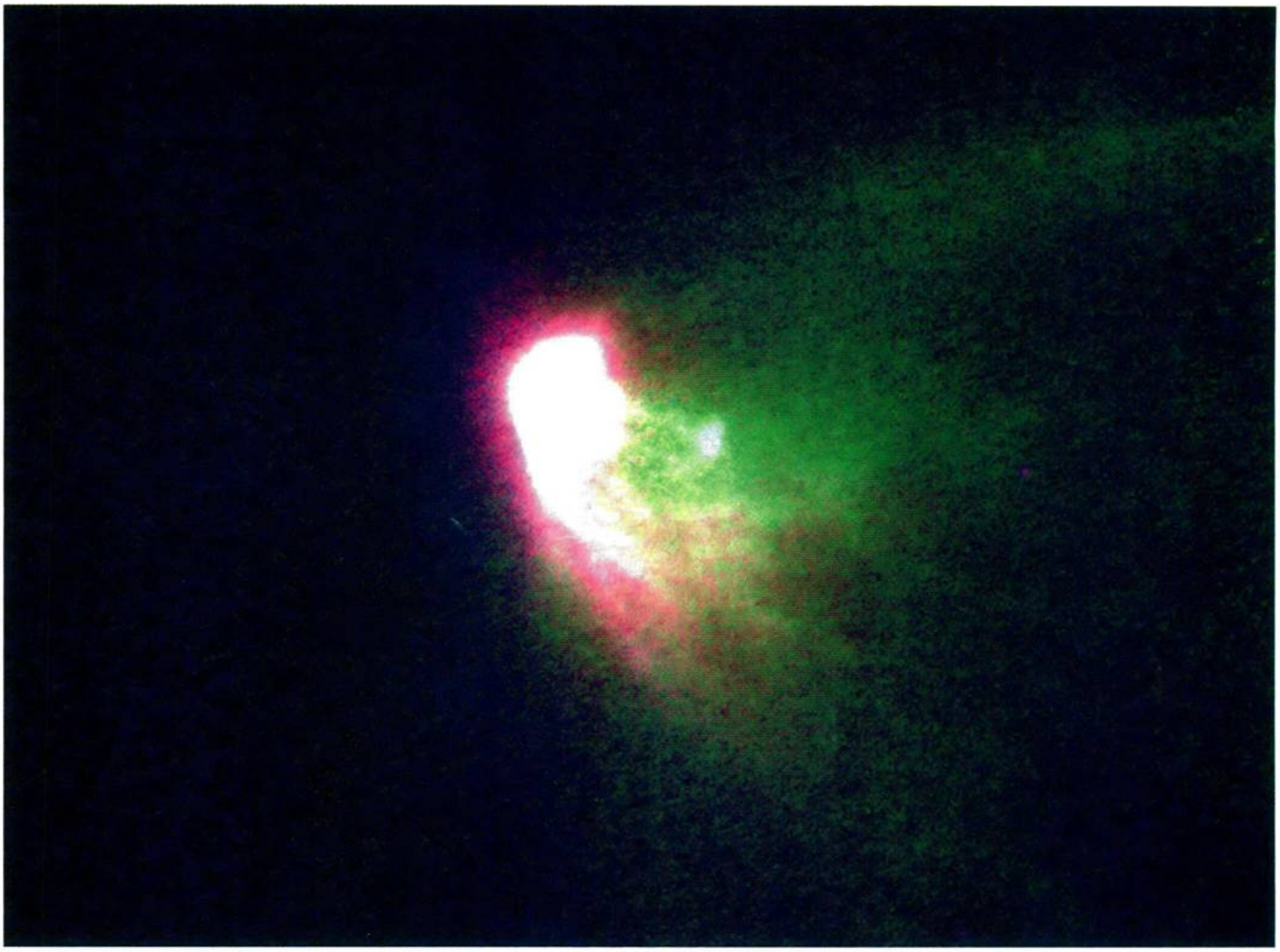
Subaru's giant primary mirror is barely 20 centimeters (8 inches) thick and has more or less the same proportions as a contact lens. The mirror's shape is automatically adjusted 100 times a second using 261 small actuators — motors with sensors — that push and pull it from behind. This counteracts the deformation of the mirrors caused by gravity, which would otherwise distort the images of stars.

The 8.3-meter Subaru Telescope and its unique cylindrical "dome" sit atop Mauna Kea.

The mirror blank was fabricated at the Corning Glass Works in New York state and then trucked to Contraves U.S.A. in Pittsburgh for three years of polishing. The mirror was loaded on a barge and floated down the Ohio River to the Mississippi, then down that river to New Orleans. It crossed the Gulf of Mexico on a larger ship, went through the Panama Canal, and traversed the Pacific to Hawaii where it was placed on a trailer and hauled up the mountain. It arrived at the observatory in November 1998 after a six-week journey.

Perhaps Subaru's greatest strength is its versatility. It has three secondary mirrors and four different foci — Cassegrain, optical Nasmyth, infrared Nasmyth, and prime focus — which guide light into seven instruments. "We need to meet many different demands because this is the only big telescope we have," explained Tetsuo Nishimura, an associate director of the observatory, as he gave me a tour. Before Subaru, the largest optical telescope Japanese astronomers could use was a 1.9-meter built in the 1960s. "We didn't have a lot of experience building telescopes or

Right: Loops and filaments highlight both the inner ring and outer halo of the Ring Nebula. Below: A thousand galaxies cluster in Abell 851, a rich grouping 5 billion light-years away.



Above: Two parallel jets (green) emanate from a pair of protostars known as L1551–IRS5. Left: Baby stars gleam amid the star-forming gas of the Orion Nebula in this infrared view.

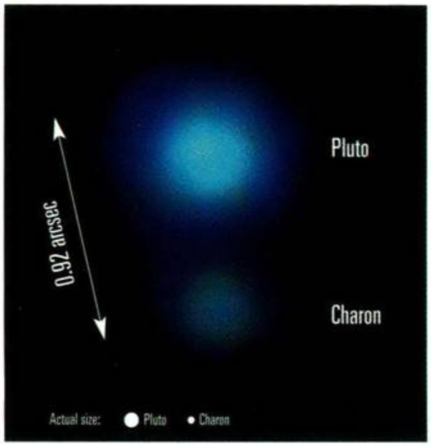
instruments, so Subaru is a very ambitious project," Nishimura added.

From a platform up high, I watched with a little trepidation as a giant robotic arm, moving at a snail's pace, carried a secondary mirror out from a storeroom on one side of the building to a focus above the primary. Even though the primary mirror was covered at the time, it was hard not to imagine the disastrous result of accidentally dropping something heavy on it.

Below the primary mirror is the Cassegrain focus floor. There are two rooms on the sides to store instruments. The various cameras and spectrographs, each exactly two meters on a side and weighing two tons, are kept on carts that run on tracks. A remote-controlled cart brings the instrument to the focus position where it is mounted on the telescope using 16 motorized bolts.

Subaru has already set a new standard in telescope technology and is now beginning to provide a variety of exciting scientific results as well. Last year, Japanese astronomers using Subaru discovered that the surface compositions of Pluto and its moon Charon are quite different from each other. Charon seems to be covered with water ice, which apparently does not exist at all on Pluto, while Charon seems to be devoid of methane and other compounds evident on Pluto.

Subaru can separate Pluto and Charon, while spectra show their surfaces to be different.



The superb image quality of Subaru has also allowed astronomers to take a picture of two parallel jets emanating from a pair of newborn stars, known as L1551–IRS5, separated by a mere 40 astronomical units. One of Subaru's first major projects, already underway, is to observe a one-degree wide area of sky down to very faint magnitudes. This Subaru Deep Field is expected to probe young galaxies in the far reaches of the universe. It may not be long before the Keck telescopes feel the competition from their new neighbor. **A**

Contributing editor Ray Jayawardhana received his Ph.D. in astronomy from Harvard University last June. Now he is a Miller Research Fellow at the University of California at Berkeley. He is the author of Star Factories: The Birth of Stars and Planets, *a book for middle schools published recently by Steck-Vaughn.*

Into the Outer Limits

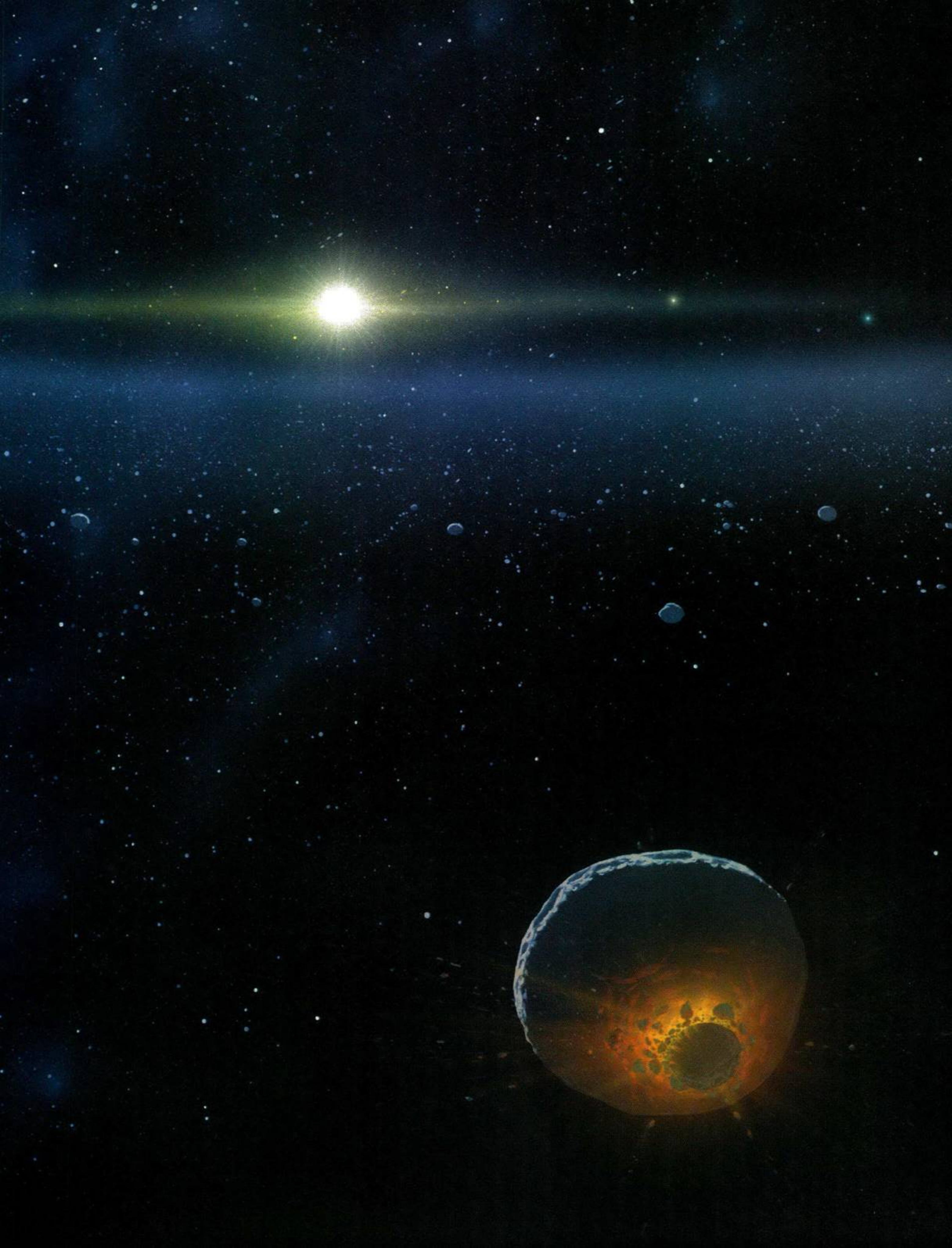
Astronomers are figuring out how the Edgeworth-Kuiper Belt formed and evolved.

by S. Alan Stern

For many decades after its discovery, Pluto appeared to be a misfit. A tiny spit of a planet with a moon nearly half its own size, this rogue world seemed to defy the apparent pattern revealed in the architecture of the solar system. How could we fit it into the well-organized architectural framework that our solar system displayed, with small planets close to the sun and giant planets afar?

Some astronomers suggested Pluto was a wayward asteroid. Others suggested it was an escaped satellite of Neptune. But two scientists got it right. British astronomer Kenneth Edgeworth and Dutch-American astronomer Gerard Kuiper suggested something entirely different: Pluto was not an oddball at all, but simply the brightest of a vast population of small, icy objects littering the region beyond Neptune.

Collisions played a dominant role in whittling down the Edgeworth-Kuiper Belt. Dan Durda



Edgeworth published the idea in 1943 and elaborated on it in 1949. Kuiper's contribution came in 1950, in a forcefully written review on planetary science as seen from the dawn of the second half of the 20th century. But Edgeworth and Kuiper were ahead of their time, for the technology to detect small, faint worlds in the dim realm beyond Neptune wasn't then available. As a result, their ideas remained untested until the 20th century had almost ended. The story that would unfold when these ideas were finally tested would reveal dramatic and unexpected hints about the origin and architecture of the outer solar system.

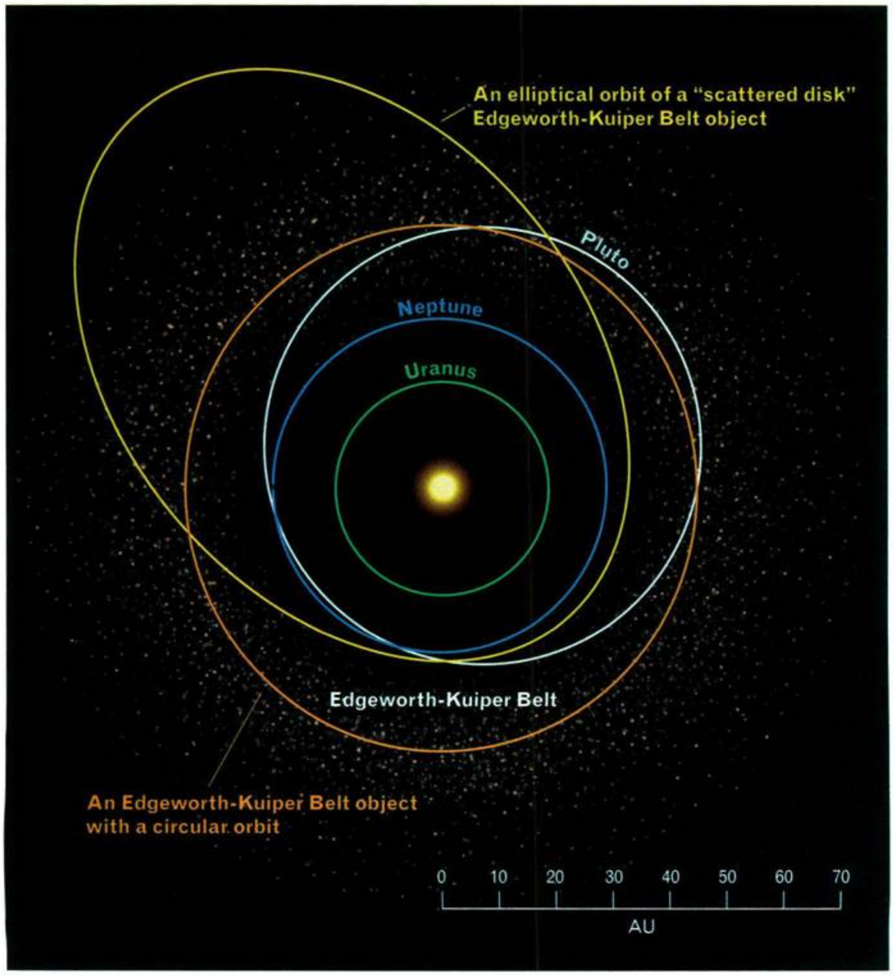
Opening the Floodgates

Astronomers suspected that short-period comets — those that take less than 200 years to orbit the sun and lie in the plane of the solar system — originate in a flattened belt or disk somewhere just beyond Neptune. Charles Kowal's discovery of Chiron in 1977 bolstered this idea. The 125-mile-wide Chiron orbits between Saturn and Uranus. Because Chiron's orbit is unstable and the object is icy, it seems to have come from beyond Neptune.

After years of unsuccessful searches for more distant objects, the dam broke in August 1992, when David Jewitt of the University of Hawaii and his graduate student Jane Luu detected the first solar system body beyond Neptune other than Pluto. This 23rd-magnitude object, 1992 QB_1, is probably about 120 miles (200 km) across. It travels in a slightly elliptical orbit centered at 44 astronomical units (AU) — 5 AU farther out than Pluto.

The discovery of 1992 QB_1 was the equivalent of the little boy who removed his finger from the dike and unleashed a flood. In 1993, five more objects were discovered in similar orbits beyond Neptune; a dozen more followed in 1994, and 16 more were spotted in 1995. As of June 2000, nearly 300 Edgeworth-Kuiper Objects (EKOs) have been detected. More than 90 percent of these EKOs follow roughly circular orbits that indicate they formed beyond Neptune, as predicted by theorists Hal Levison and Martin Duncan. But astronomers have also found about two dozen objects on highly inclined, elliptical orbits stretching out as far as 200 AU. These objects, which compose a population called the "scattered disk," probably formed slightly closer to the sun but were later ejected by Uranus and Neptune.

Assuming a dark surface such as those on comets, the brightness of the known EKOs indicates they have diameters exceeding 60 miles (100 km). The largest known EKOs probably have diameters exceeding 300 miles (500 km), larger than any asteroid except Ceres.


An elliptical orbit of a "scattered disk" Edgeworth-Kuiper Belt object
Pluto
Neptune
Uranus
Edgeworth-Kuiper Belt
An Edgeworth-Kuiper Belt object with a circular orbit
0
10
20
30
40
50
60
70
AU

The Tip of the Iceberg

Despite the deluge of recent EKO discoveries, observers have barely scratched the surface of what lies in the Edgeworth-Kuiper Belt. Astronomers have searched far less than one percent of the region around the ecliptic for EKOs. Based purely on the fraction of the sky searched to date and the number of discoveries made, we estimate that as many as 100,000 EKOs with diameters greater than 60 miles, along with a billion or more kilometer-scale comets, lie inside 50 AU. Altogether, this indicates that the region between Neptune's orbit at 30 AU and the outer edge of Pluto's orbit at 50 AU contains roughly one-third of an Earth mass of material.

Although small compared to the mass of Neptune (which has 17 times the mass of Earth), the transneptunian region is nevertheless teeming with bodies. The region, which spans a distance about 10 times as large as the asteroid belt, has more than 300 times the mass of all the asteroids *combined.* Pluto is thus no longer seen as a rogue misfit among the giant planets, but as the reigning king of the Kuiper Belt.

Planetary astronomers dissecting the faint light of EKOs are finding that EKOs span a range of colors from neutral gray to very red, indicating these bodies have a variety of surfaces. Even more tantalizing, spectra of their surfaces show evidence of water ice, and in some cases, perhaps even hydrocarbons such as methane — much like the surfaces of Pluto and Neptune's largest moon Triton. As a population, the EKOs are turning out to be as interesting and diverse as the asteroids.

As astronomers focus more attention and better instrumentation on the physical nature of EKOs, these objects are sure to reveal more surprises. Astronomers are now asking whether many EKOs possess satellites, whether some show signs of atmospheres and surface activity, and what exotic ices and minerals may lie on their surfaces.

Big Bangs Abound

My own research in exploring the Edgeworth-Kuiper Belt began in 1994 with a computer model that evaluated the role of collisions. Astronomers have known for many decades that collisions are the dominant process shaping the evolution of objects in the asteroid belt, determining the range of sizes for all but the largest objects.

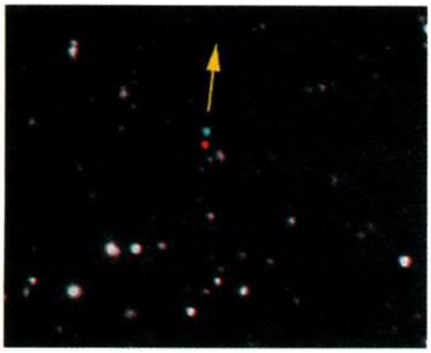
As it turns out, collisions are as important in the Edgeworth-Kuiper Belt as they are in the asteroid belt. One of my earliest findings revealed a big surprise: The larger EKOs, those with diameters greater than about 30 miles (50 km), can survive the pummeling from smaller projectiles. But objects smaller than about 20 miles in diameter cannot survive the collisional environment over the 4.6-billion-year history of the solar system. As a result, comet-sized bodies in the Edgeworth-Kuiper Belt, and therefore most of the short-period comets themselves, must be *much* younger than the solar system, perhaps less than 500 million years old.

In 1996 and 1997, Don Davis and his late colleague Paolo Farinella used sophisticated computer models to show this point more convincingly. They also demonstrated that collisions could nudge fragments out of the Edgeworth-Kuiper Belt and into orbits that would bring them "down" to the inner solar system. Many of these are the short-period comets that we see every year.

More recently, my colleague Dan Durda and I have examined the role of impacts in modifying the surfaces of the larger EKOs. We showed that these objects should develop an impact-generated outer crust that is highly modified by collisions, with craters of various sizes. The impacts themselves, which typically occur at velocities of 1,100 to 2,200 miles per hour, should generate enough energy to flash off some of the more volatile surface ices, such as methane. When we see EKOs with methane or other extreme volatiles on their surfaces, these materials must have only recently been exposed, perhaps through impacts.

Ghost of the Belt Before?

But perhaps the single most surprising result we obtained concerns the formation of large EKOs. The formation of solid bodies in the solar system took place through successive collisions between smaller objects that built the larger bodies "from the bottom up." In the solar system's early days, the dust, rocks, and planetesimals from which the planets were made followed more or less circular orbits around the sun. Because these bodies had similar orbits, they collided with one another at low relative velocities. Because the collisions were not particularly violent, bodies could stick together and grow larger.



Astronomers discovered this Edgeworth-Kuiper Belt object by seeing how it moved over 2 hours. The arrow shows the direction of motion. Robert Millis, Marc Buie (Lowell Observatory), et al.

But when Davis, Farinella, and I applied standard planet formation models to the Edgeworth-Kuiper Belt, we found something amazing: The 60-mile-diameter and larger EKOs could not possibly have been formed in the Edgeworth-Kuiper Belt that we see today! Why? First, the collisions occurring today are too violent to permit accretion. After Neptune formed and reached its current size, its gravity pumped up the orbital eccentricities of objects in the outer solar system. Bodies with elliptical orbits smash into one another like high-speed bullets. Rather than sticking together, they shatter. Second, even if the collisional environment was gentle enough to allow growth, the density of these objects in space is so low that collisions occur too infrequently to allow the growth of large EKOs even in 10 times the age of the solar system.

The existence of large EKOs tells us that the Edgeworth-Kuiper Belt was far more massive in the early days of the solar system than it is today. With a greater supply of material, there would have been more frequent collisions and consequently a fast enough growth rate to make the large EKOs. Just how much material was required? As it turns out, roughly 30 Earth masses. During the past 4.6 billion years, as the transneptunian region evolved, it apparently lost about 99 percent of its mass.

Computer simulations show that this evolution may have taken place as follows: Early in the history of the solar system, perhaps in the first 100 million years or so after the sun formed, EKOs were able to grow in the massive disk that existed between 30 and at least 50 AU from the sun. When Neptune was almost fully grown, its gravitational influence perturbed orbits in the 30 to 50 AU region to such an extent that collision speeds increased, meaning collisions destroyed bodies instead of building them up. This stopped the growth of transneptunian bodies in midstride. Most of the mass in the original disk, out to distances perhaps as great as 70 AU, was lost as collisions ground material up into fine dust, which was then whisked out of the solar system by the pressure exerted by sunlight.

Our computer simulations show that Neptune could easily have caused a 30-Earth-mass Edgeworth-Kuiper Belt to erode itself down to the roughly 0.3-Earth-mass structure we see today. During the grinding process that depleted the belt of mass, the solar system might have looked like the dusty, massive disk around the star Beta Pictoris. This 100-million-year-old disk appears to be a remnant that results from colliding planetesimals in Beta Pictoris's own Edgeworth-Kuiper Belt.

If this scenario is correct, it suggests something even more exciting may lurk beyond 70 AU: the remnants of the ancient, massive Edgeworth-Kuiper Belt. Several groups are probing ever-deeper into the outer solar system to determine whether or not this massive disk indeed lurks far into the depths of interplanetary space. There's a good chance they will find objects in these distant reaches of the solar system, possibly including bodies much larger than Pluto. With tools at their disposal such as the European Southern Observatory's Very Large Telescope, the twin Keck Telescopes, and in December 2001, NASA's Space Infrared Telescope Facility, the answer should soon be in hand. A

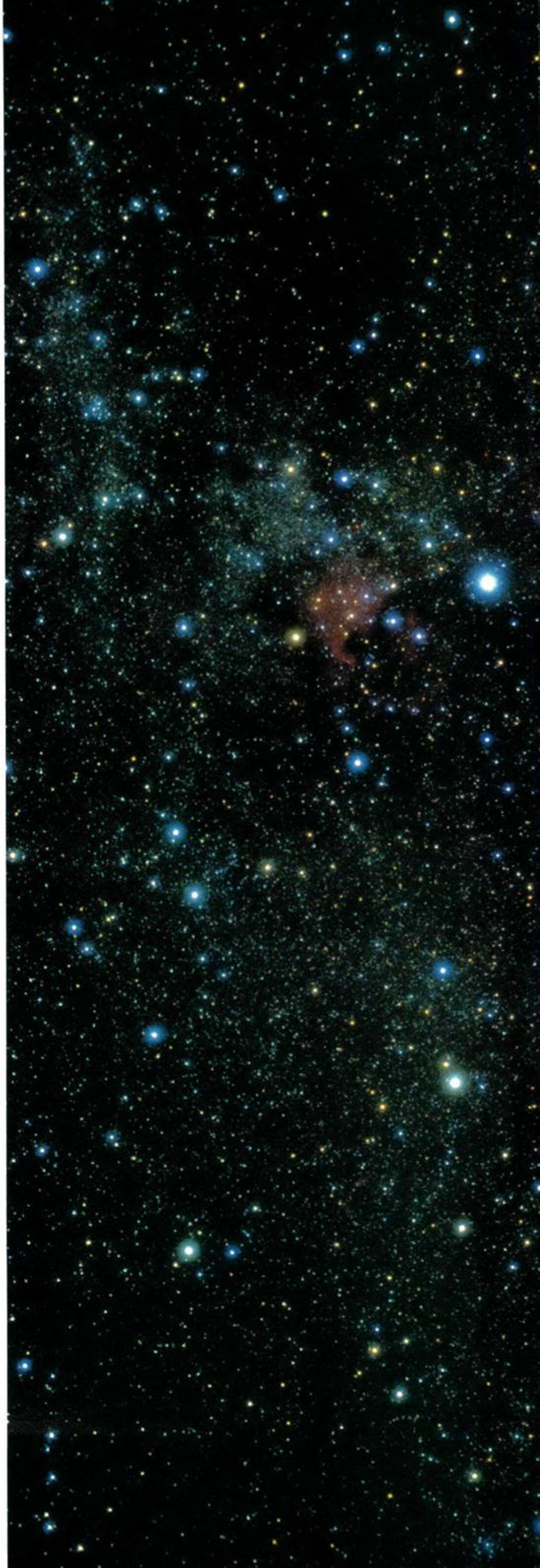
S. Alan Stern is the director of the Southwest Research Institute's Space Science Department in Boulder, Colorado. He coauthored the book Pluto and Charon *and edited* Our Worlds.

Double Trouble

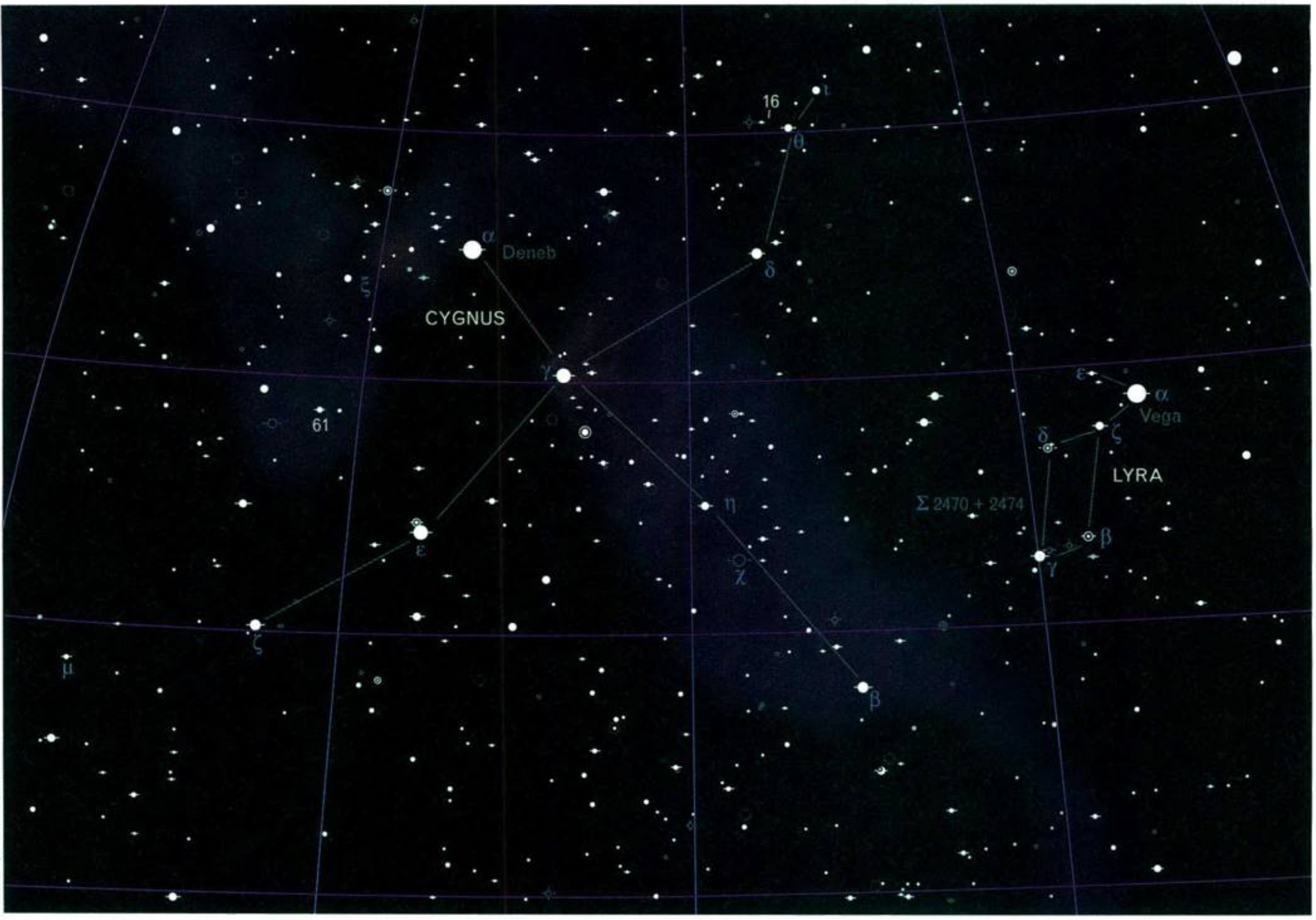
A pair of summer constellations holds a multitude of binary star treasures.

Photos by Akira Inaka
Text by Kelly Kizer Whitt

On a moonless summer night the Milky Way flows overhead. Cygnus the Swan swims its length with Lyra the Lyre to the west. This region, thick with innumerable suns, offers up a bountiful crop of double stars. Only a handful of observers regularly reap the plentiful twins that a summer's night sky has to offer. You can join their ranks with just modest equipment: a lawn chair and binoculars or a 4- to 6-inch telescope. Country folk can even spot some doubles with the naked eye.



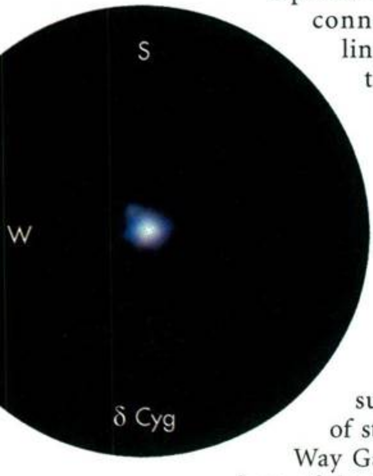
Dozens of double stars smother the regions around the summer constellations Cygnus and Lyra.



Astronomy: Kellie Jaeger

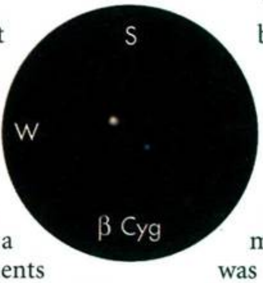
Double stars can be true doubles, also known as binary stars, or optical doubles. A true double is a system in which the stars are physically connected, either due to rotation around a common center of gravity or by sharing proper motion through space. Optical doubles appear connected due to a line-of-sight positioning but in fact lie far apart. Many stars that appear double in backyard telescopes are really multiple stars with three or more components.

Unlike our sun, the majority of stars in the Milky Way Galaxy are members of double or multiple star systems. The following eight double stars are just starting points for the abundant pairs that can be found swarming near the Milky Way and sprinkled throughout the sky. On the above map, all the circles with a line through them are multiple stars.



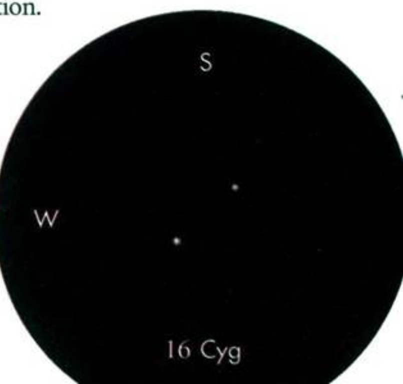
Seeing Double in Cygnus

The honor of the "most famous" double star in the sky belongs to **Albireo** (Beta [β] Cygni). Albireo marks the "head" of Cygnus the Swan, or the "foot" of the Northern Cross. Best viewed with a small telescope, the components of Albireo are separated by about 35". The love and admiration given to Albireo stems from the spectacular color contrast between its blue (spectral type B) and orange-yellow (spectral type K) members. The yellow star shines at 3rd magnitude, and the blue star is somewhat dimmer at 5th magnitude. This binary system has a bonus feature: The Cygnus star cloud floats behind them.



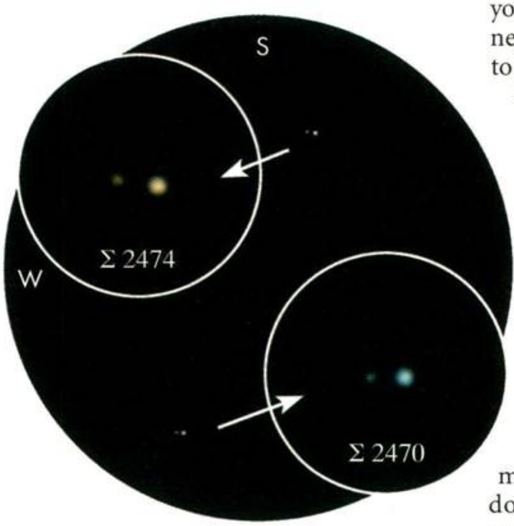
A challenge in Cygnus for small telescope owners is **Delta** (δ) **Cygni**, the star that denotes the western end of the Northern Cross's lateral bar. The 2nd-magnitude primary of Delta Cyg lies just 2.5" from its 6th-magnitude companion. The bluish stars orbit each other and are nearing their maximum separation.

The next target can be split by larger binoculars and shines in orange and red tones. Due to its large proper motion, the historical **61 Cygni** was once called "The Flying Star" by an Italian astronomer and monk, Giuseppe Piazzi. 61 Cyg was the first star to have its distance from Earth measured accurately. In 1838, a German named Friedrich Wilhelm Bessel calculated 61 Cyg's distance at about 10 light-years, not far from today's estimate of 11 light-years. Thus, 61 Cyg lies close to our solar system, accounting for much of its large proper motion.



The star system 61 Cyg lies 6.5° east of Deneb, which is Cygnus's contribution to the summer triangle. The 5th-magnitude, spectral type K, orange stars are 30" apart. Astronomers have detected a third possible member, 61 Cygni C, which may be a brown dwarf several times larger than Jupiter.

The last target in Cygnus, **16 Cygni**, lies one binocular field north of Delta Cyg. This double star system has a 39" separation. The spectral type G stars appear similar in brightness at 5th magnitude. Although you can't see it, the fainter member possesses a planet discovered in 1996 by Bill Cochran and Artie Hatzes from the University of Texas and Paul Butler and Geoff Marcy of San Francisco State University and the University of California at Berkeley. The planet contains 1.7 Jupiter masses and has a highly elliptical orbit, which may be a result of the double star interactions.

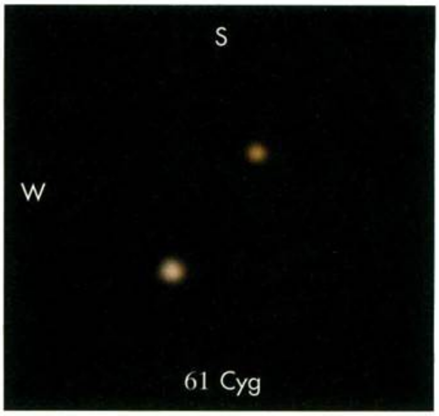


Doing a Double Take in Lyra

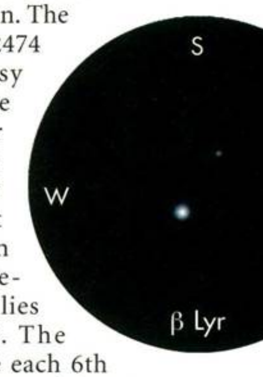
Moving west we come across the small constellation Lyra the Lyre. Bright Vega anchors the constellation, and a small parallelogram between Vega and Cygnus marks the body of the lyre (harp). **Beta Lyrae** denotes the southwestern point and is best known as a variable star. The main component, an eclipsing binary, fluctuates between magnitudes 3.4 and 4.3 every 13 days. A wide 46" separates it with its visual partner of 7th magnitude. The two stars show characteristics of being a true physical system, and a 9th-magnitude third member floats 86" away.

Delta Lyrae, with a 10.5' separation, can be split with the naked eye. If you're observing with a telescope, you'll need a low-power wide-field eyepiece to capture these two in the same field. Despite their distance from each other, they both race along at 15.5 miles per second and thus are probably a binary system. These 4th- and 5th-magnitude stars mark the northeast corner of the parallelogram and display beautiful red and blue hues.

Next we come to the famous "**Double-Double**," Epsilon (ε) Lyrae. Just 1.5° northeast of brilliant Vega, your naked eye may be able to make out the double system separated by 3.5'. A telescope reveals that each of the double stars is also a double star, thus the nickname "Double-Double." The northern double, Epsilon¹, is a pair of 5th- and 6th-magnitude stars with a separation of just 2.8". The southern double, Epsilon², is a pair of 5th-magnitude stars separated by 2.6". These four white stars are at right angles to one another: If you were to extend a line through each pair, the two lines would intersect in a perpendicular manner.



Our last star system also has four members. The quadruple star system of **Struve (Σ) 2470** and **Struve 2474** can be viewed as a naked-eye double, but it takes a 4- to 6-inch scope to make out its extra duplicity. The two stars in Σ 2470 have a 13" separation, and Σ 2474 sports a 16" separation. The location of Σ 2470 and Σ 2474 puts it far from any easy signposts, so it's best to use the star map to hop your way to it, but a rough measurement would put it halfway between the bright stars Vega and Albireo. In contrast to the Double-Double, this quadruple lies parallel to each other. The brighter components are each 6th magnitude and the dimmer shine at 8th magnitude.



The binocular and telescopic doubles listed here are just the tip of the iceberg. See what other double, triple, and quadruple star systems you can find as you star-hop your way across the galaxy. ■

NOTEWORTHY DOUBLE STARS IN CYGNUS AND LYRA

Name	R.A.	Dec.	Magnitudes	Separation	Position Angle
Beta (β) Cygni (Albireo)	19h30.7m	27°58'	3.2, 5.4	34.3"	54° (1967)
Delta (δ) Cygni	19h45.0m	45°08'	2.9, 6.3	2.5"	—
61 Cygni	21h06.9m	38°45'	5.4, 6.3	30"	—
16 Cygni	19h41.8m	50°31'	6.0, 6.2	39.4"	134° (1976)
Beta (β) Lyrae	18h50.1m	33°22'	3.9, 7.8	46"	149° (1955)
Delta (δ) Lyrae	18h54.5m	36°54'	5.5, 4.5	10.5'	349° (1923)
Epsilon (ε) Lyrae (Double-Double)	18h44.3m	39°40'	5.0, 6.1 5.2, 5.5	3.5'	357° (1976) 94° (1975)
Σ 2470 Σ 2474	19h08.8m 19h09.1m	34°46' 34°36'	6.6, 8.6 6.7, 8.8	13.4" 16.2"	271° (1933) 262° (1974)

Akira Inaka is an astrophotographer in Japan. Look for many of his images in Astronomy's *special 3-D issue in December. Kelly Kizer Whitt is photo editor and copy editor of* Astronomy. *Her latest article, "Astronomy by the Book," appeared in the July 2000 issue.*

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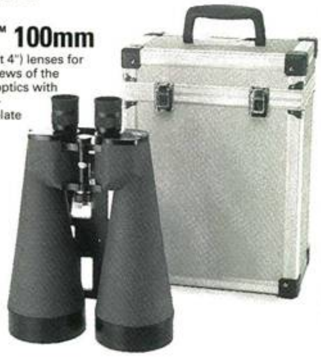

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6.3mm, 7.5mm, 10mm, 12.5mm, 17mm, 20mm, 26mm	$49.95 each

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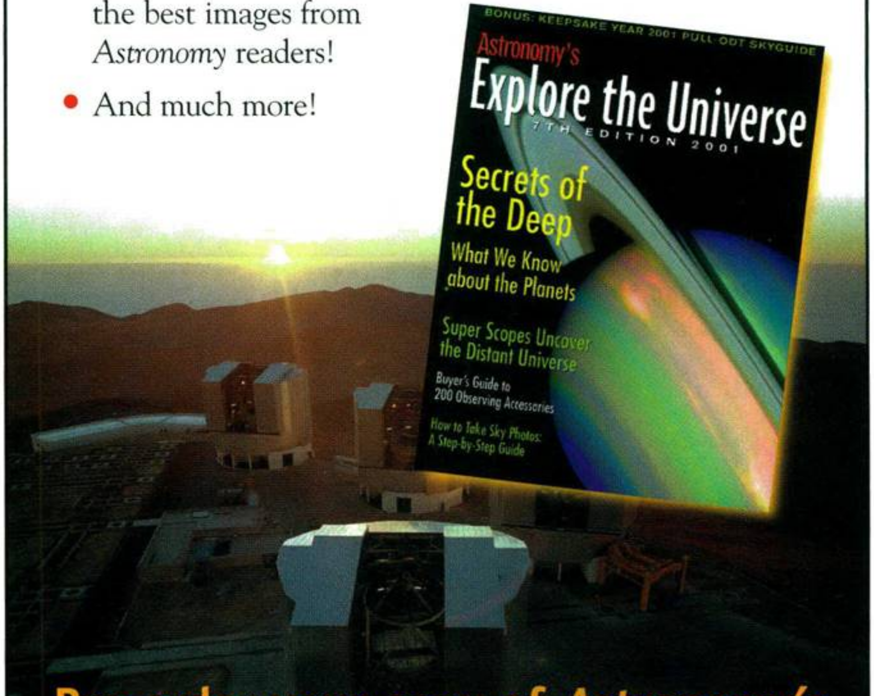
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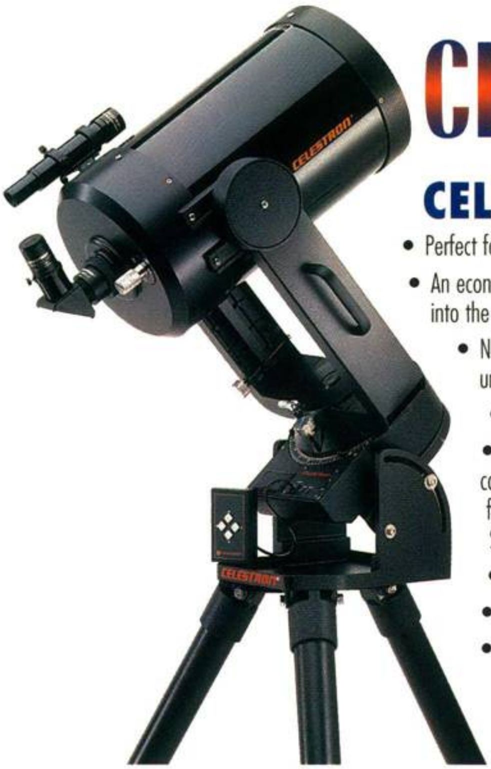
CELESTAR 8 TELESCOPES



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- Perfect for a first time astronomer.
- An economical but full featured 8" (2032mm f/10) Schmidt-Cassegrain. A considerable amount of engineering work went into the design of the Celestar 8.
- No sacrifice was made in the optics. Celestron's carefully hand-figured system delivers diffraction-limited optics of unsurpassed quality. Starbright® coatings are standard.
- The energy efficient DC electronics are powered by a 9 volt alkaline battery for easy astronomy on the go.
- The totally cordless electronics have a built-in drive corrector which is activated when using the optional hand control. The R.A. motor's main tracking speed is an accurately regulated sidereal rate. The optional hand control allows for fast and slow override of R.A. tracking speed and ± operation of the optional DEC motor. A comment from the Sky & Telescope review – "the digital electronics delivered a near-perfect sidereal tracking rate."
- The Celestar 8 drive can operate in the Northern or Southern hemisphere from 0° to 90.°
- The unique Wedgpod is a combination tripod and wedge which is very stable.
- Made in the U.S.A.
- Standard accessories include: 6x30 Finderscope, Star Diagonal – 1¼" and a 25mm SMA Eyepiece – 1¼" (81x).
- Weight – 41 pounds.

CELESTAR 8 DELUXE

- For the more serious astronomer.
- This telescope utilizes the same superior optics and has all the features of the Celestar 8, but is enhanced, for those who prefer a premium version.
- This model has a heavier duty fork mount and drive base, with a precision worm gear drive system.
- Superior tracking accuracy is attained with this advanced drive system, which has four tracking rates and PEC (Periodic Error Correction).
- For the kind of versatility that makes observing a pleasure, the hand controller makes available a micro guide rate of .5x sidereal and a slew rate of 8x sidereal.
- The stepper motor drive electronics are cordless and operate on two 9 volt batteries.
- The Celestar 8 Deluxe has many features that are necessary for the more serious amateur astronomer, particularly if you're interested in astrophotography or CCD imaging with the PixCel or other CCD cameras.
- Fastar compatible for f/1.95 CCD imaging – deep sky images in 30 seconds or less!
- Made in the U.S.A.
- The standard accessories for this telescope include: Declination Motor, Car Battery Adapter, Hand Controller, Wedge and a Tripod with adjustable height that's exceptionally rigid and sturdy .
- Also standard is a large 9x50 Finderscope, Star Diagonal – 1¼" and a multi-coated 26mm Plossl Eyepiece – 1¼" (78X).
- Weight – 52 pounds.

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Contains an RS-232 serial interface to enable usage with programs like "The Sky"™ by Software Bisque.

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sky Show

september

September ushers in autumn with a return to planetary viewing.

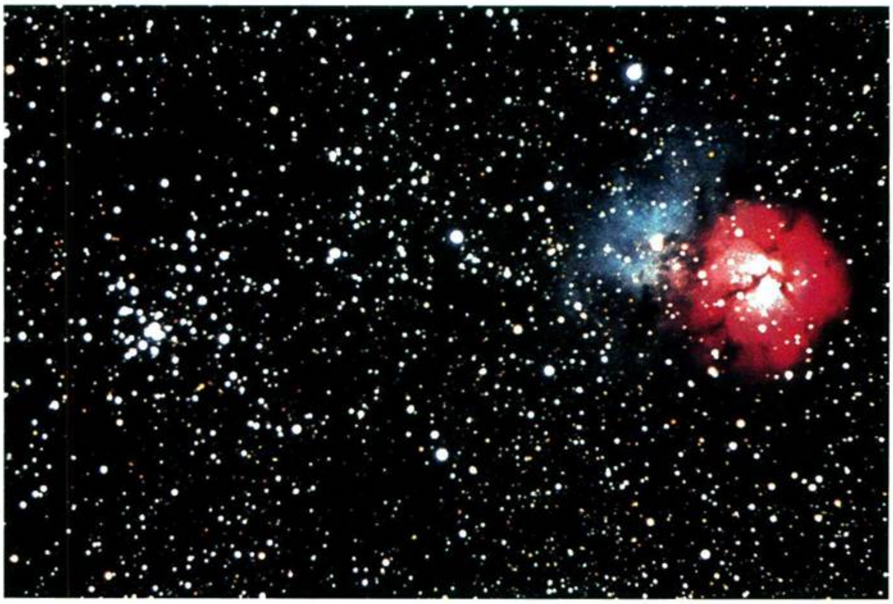
by Martin Ratcliffe and Alister Ling

▶ Summer brought a lull in activity for planet watchers, but now Venus has begun its journey into the evening sky. Its brilliant luster is almost lost in the golden glow of twilight, so use binoculars to find it low in the southwest. On the 29th the thin crescent moon hangs one binocular field to the upper right. Slowly but surely, Venus will creep higher over the coming weeks and once again assume the throne as the prominent, blazing evening star.

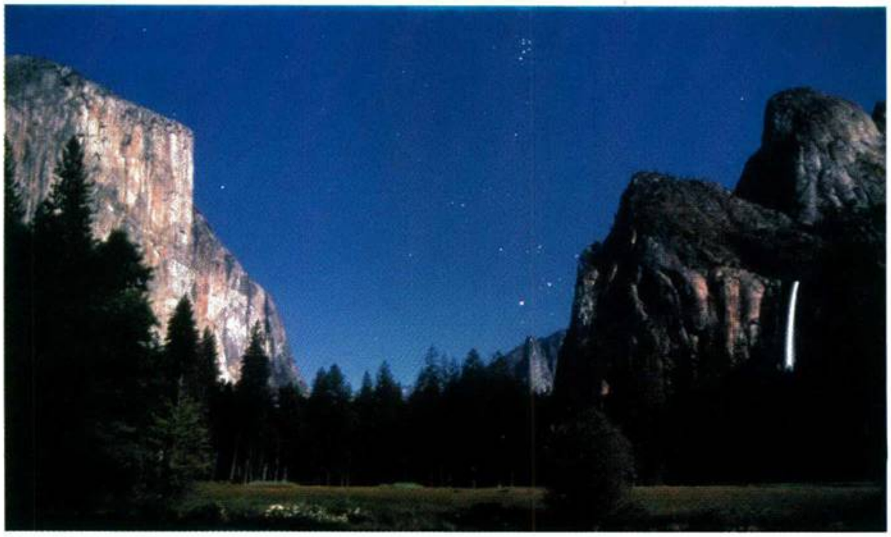
Even better, Jupiter and Saturn rise before midnight, reclaiming their roles as the most fascinating objects in the sky. After midnight on September 5/6, Jupiter sports two small black eyes, caused by the shadows of Io and Europa. The moondance and shadows of the four Galilean worlds are a continual source of delight.

The crown jewel of the night is without doubt Saturn and its beautiful rings. Look closely where the planet's disk cuts in front of the rings, and you will see a thin shadow cast onto them.

As autumn approaches in the Northern Hemisphere, watch Jupiter's naked-eye slow dance near the Pleiades and Hyades. It slides eastward until the end of the month, then moves retrograde (westward), all because Earth is catching up on its faster, inner orbit.



The star cluster M21 lies not far from the Trifid Nebula. Michael Stecker



The Pleiades and Hyades star clusters appear in the background of El Capitan. Frank Zullo

On the 19th, the moon joins the star clusters and Jupiter. The moon's dynamic motion gives us more than a simple opportunity to watch it pass through its phases. Its motion in front of stars causes them to wink out. On the evening of the 6th, the moon occults the bright star cluster M21. Many stars will vanish and then reappear one by one as the dark limb of the moon invades their territory. The next night, most North Americans have the chance to see a bright duo of stars, Nu^1 (ν^1) and Nu^2 (ν^2) Sagittarii, succumb to the moon's inevitable progression.

Beauty comes in many forms. Grab some binoculars and head out of town to see the vast river of stars called the Milky Way. Midway up the sky in the south you can see a dark lane of dust and gas called the Great Rift. As you scan down the branch on the right, you will find some fine open star clusters often overlooked for the sparkles of the more populated opposite branch of the Milky Way.

2000 September

5 First quarter moon is at 12:27 P.M. EDT

7 Jupiter passes 5° north of Aldebaran, 2 P.M. EDT

8 The moon is at apogee (251,507 miles from Earth), 8:36 A.M. EDT

9 The moon passes 1.2° south of Neptune, 7 P.M. EDT

10 The moon passes 1.4° south of Uranus, 9 P.M. EDT

12 Saturn is stationary, 4 P.M. EDT

13 Full moon is at 3:37 P.M. EDT

16 Mars passes 0.8° north of Regulus, 3 A.M. EDT

18 Venus passes 3° north of Spica, 3 P.M. EDT (page 71)
The moon passes 1.8° south of Saturn, 9 P.M. EDT (page 71)

19 The moon passes 2° south of Jupiter, 3 P.M. EDT (page 71)

20 Last quarter moon is at 9:28 P.M. EDT

22 Autumnal equinox is at 1:27 P.M. EDT

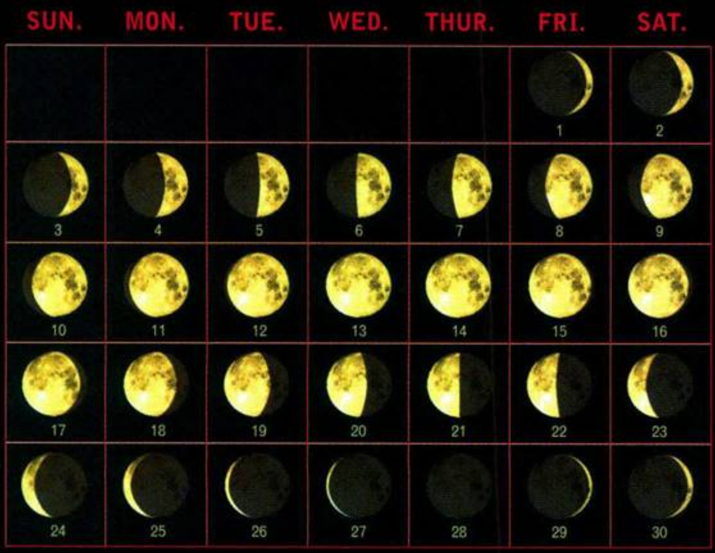
23 Mercury passes 0.7° north of Spica, 11 A.M. EDT

24 The moon is at perigee (228,019 miles from Earth), 4:22 A.M. EDT

25 The moon passes 2° north of Mars, 1 P.M. EDT

27 Asteroid Lutetia is at opposition, 2 P.M. EDT
New moon is at 3:53 P.M. EDT

29 Jupiter is stationary, 10 A.M. EDT
The moon passes 5° north of Venus, 8 P.M. EDT


SUN.
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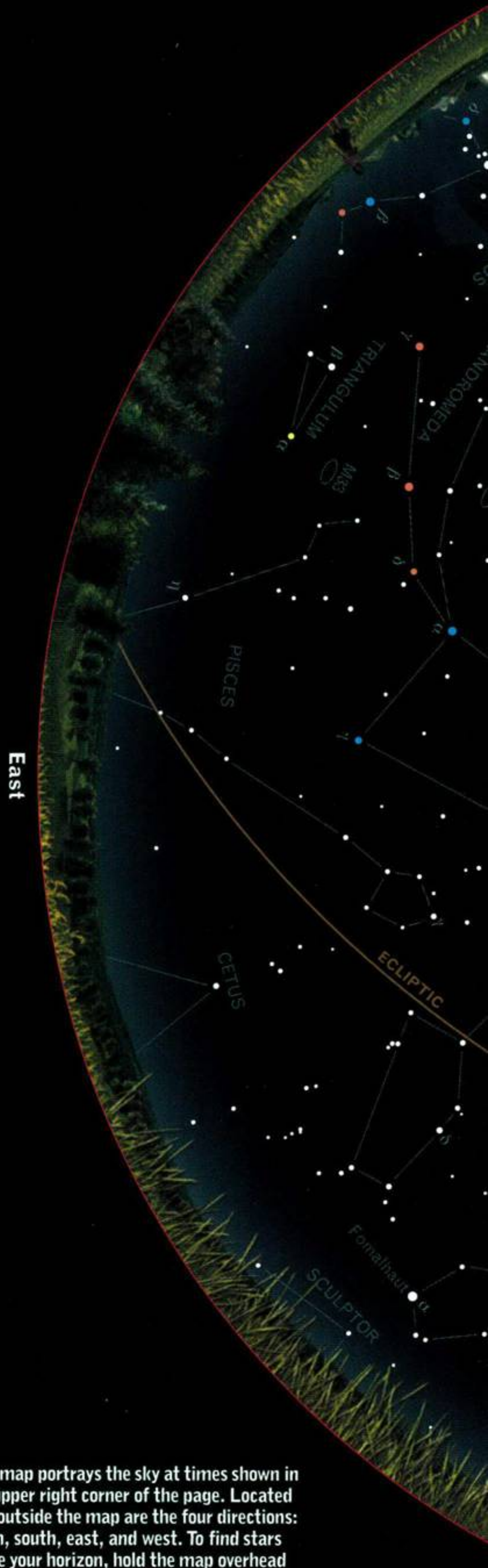
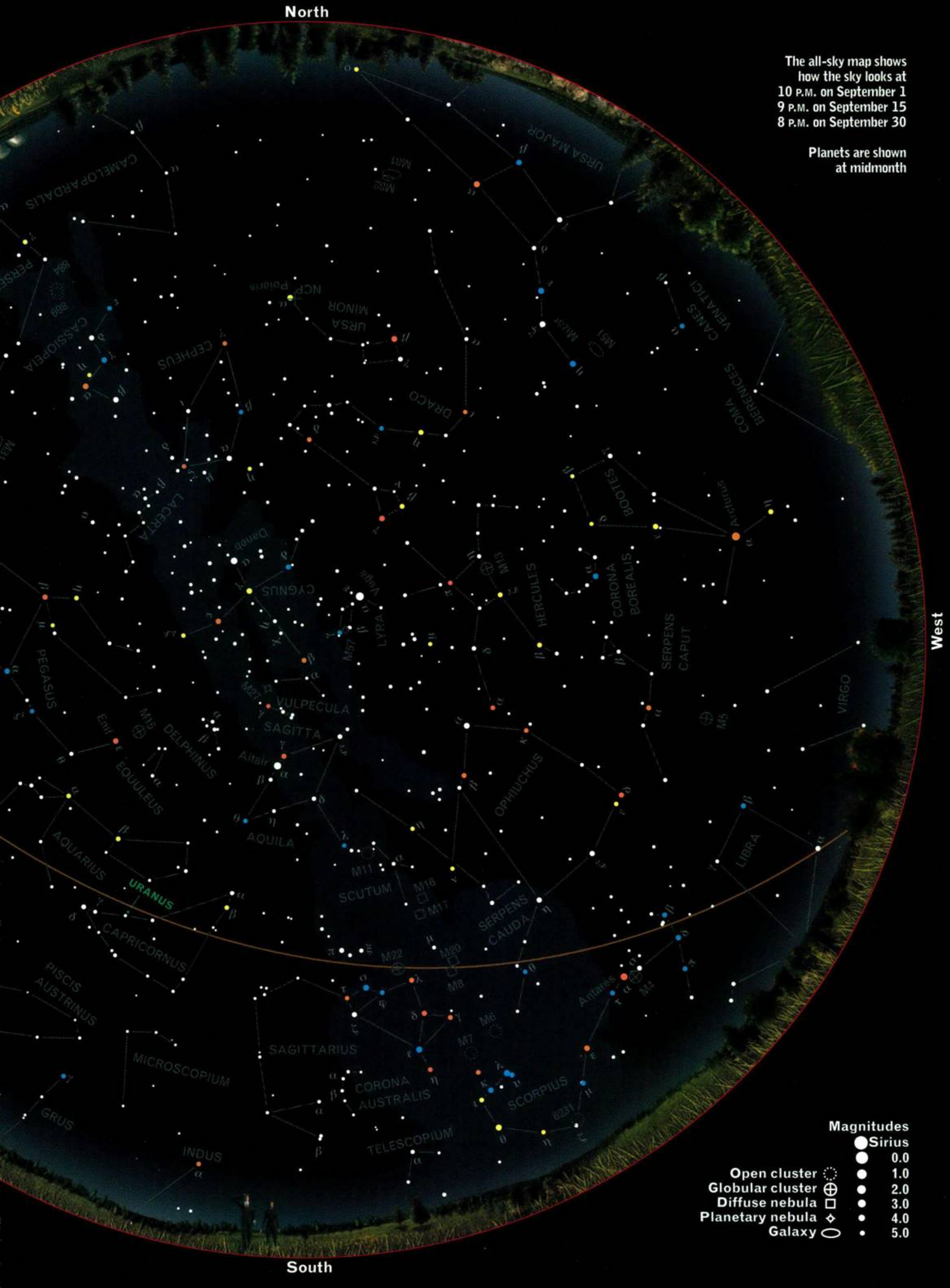

East
TRIANGULUM
ANDROMEDA
M33
PISCES
ECLIPTIC
CETUS
Fomalhaut
SCULPTOR

This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

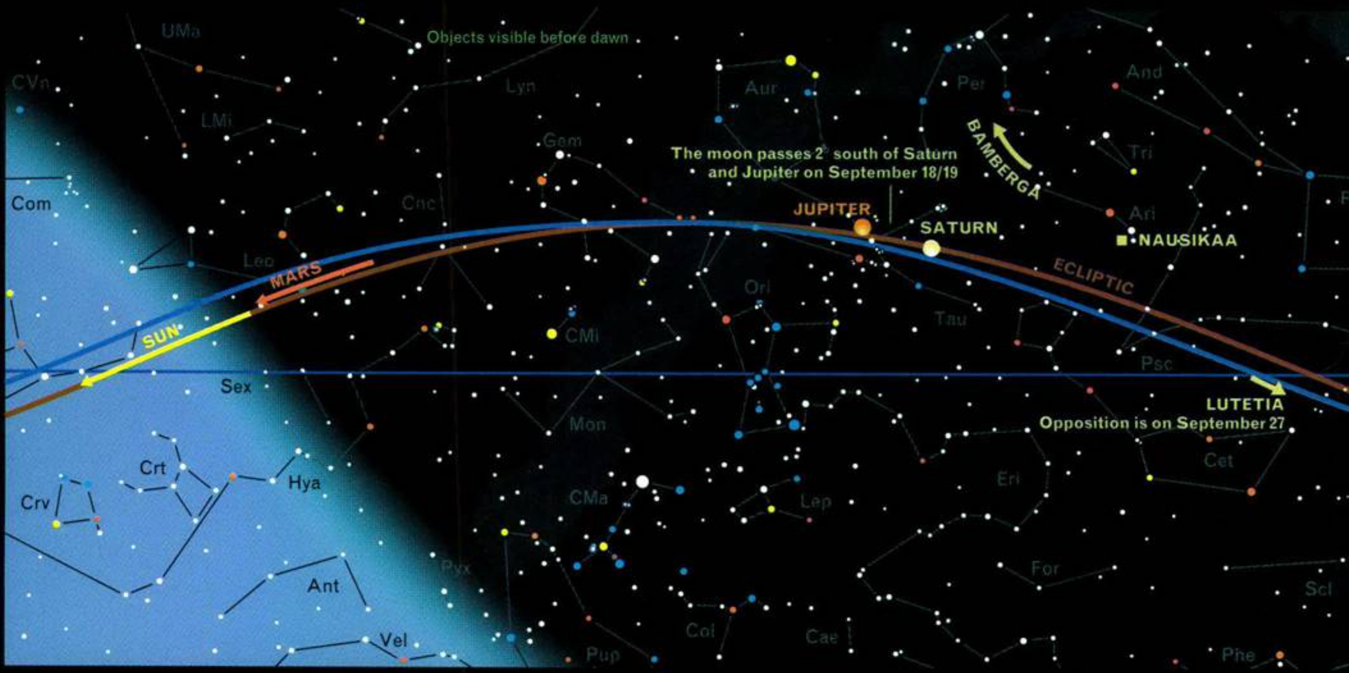

North
South
West
URSA MAJOR
CAMELOPARDALIS
PERSEUS
CASSIOPEIA
NCP Polaris
URSA MINOR
CEPHEUS
DRACO
CANES VENATICI
Mizar
M51
M81
M82
COMA BERENICES
LACERTA
Deneb
CYGNUS
Vega
LYRA
M57
HERCULES
M13
CORONA BOREALIS
BOOTES
Arcturus
SERPENS CAPUT
VIRGO
M5
PEGASUS
Enif
M15
M27
VULPECULA
SAGITTA
DELPHINUS
Altair
EQUULEUS
OPHIUCHUS
AQUILA
AQUARIUS
URANUS
SCUTUM
M11
M16
M17
SERPENS CAUDA
LIBRA
CAPRICORNUS
M22
M20
M8
Antares
M4
PISCIS AUSTRINUS
SAGITTARIUS
M6
M7
MICROSCOPIUM
CORONA AUSTRALIS
SCORPIUS
6231
GRUS
TELESCOPIUM
INDUS
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows
how the sky looks at
10 P.M. on September 1
9 P.M. on September 15
8 P.M. on September 30

Planets are shown
at midmonth

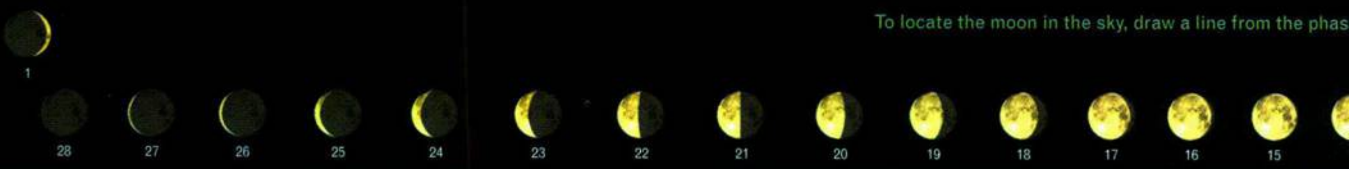
Path of the Planets

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system obje



Objects visible before dawn
UMa
CVn
LMi
Lyn
Aur
Per
And
Tri
Ari
Gem
Com
Cnc
Leo
MARS
SUN
Sex
Crt
Crv
Hya
Ant
Vel
Pyx
Pup
CMi
Mon
CMa
Ori
Tau
Lep
Col
Cae
Eri
For
Psc
Cet
Scl
Phe
The moon passes 2° south of Saturn and Jupiter on September 18/19
BAMBERGA
JUPITER
SATURN
■ NAUSIKAA
ECLIPTIC
LUTETIA
Opposition is on September 27

To locate the moon in the sky, draw a line from the phas



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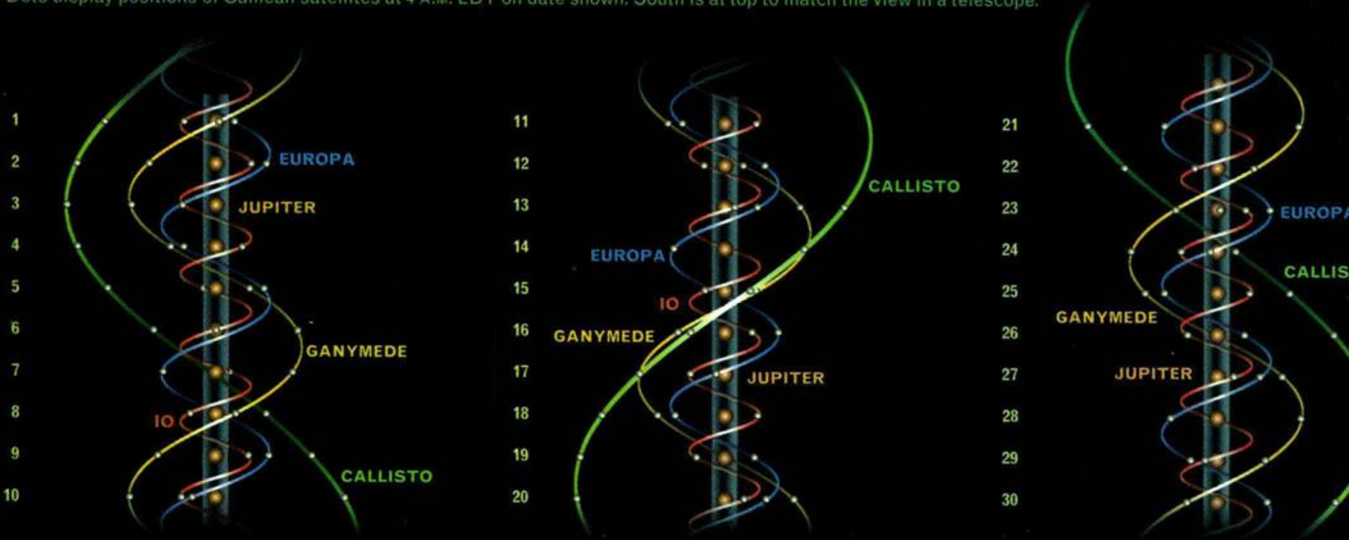
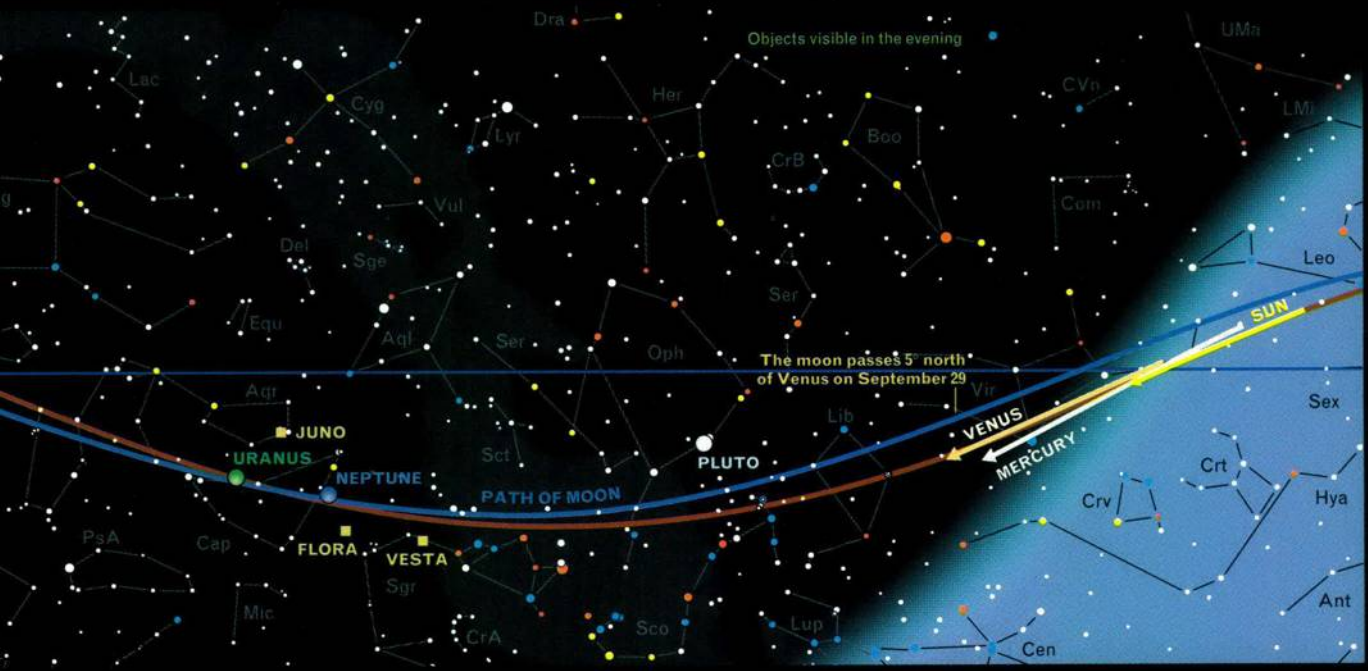
PLANETS	**MERCURY**	**MERCURY**	**VENUS**	**MARS**	**JUPI**
Date	September 15	September 30	September 15	September 15	Septem
Magnitude	−0.2	0.0	−3.9	1.8	−2
Angular Size	5.3''	6.1''	11.3''	3.7''	41.
Illumination	85%	71%	90%	98%	99
Distance (AU) from Earth	1.278	1.098	1.483	2.524	4.7
Distance (AU) from Sun	0.459	0.459	0.724	1.654	5.0
Right Ascension (2000.0)	12h40.6m	13h55.2m	13h08.1m	10h05.2m	4h37
Declination (2000.0)	−4°44'	−14°10''	−6°35'	13°03'	21°

Jupiter's Moons

Dots display positions of Galilean satellites at 4 A.M. EDT on date shown. South is at top to match the view in a telescope.



ts during the month.


Dra
Objects visible in the evening
UMa
Lac
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Lyr
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CVn
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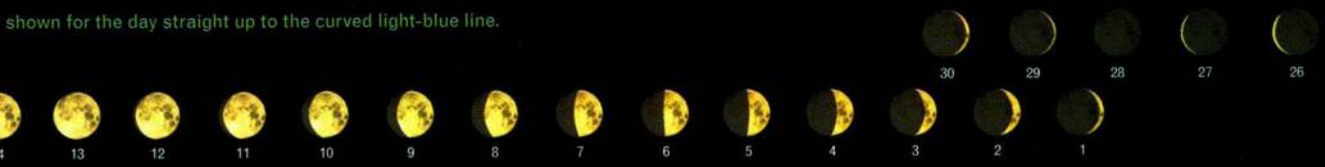
Ser
Equ
SUN
Aql
Ser
Oph
The moon passes 5° north of Venus on September 29
Aqr
Vir
Sex
JUNO
Lib
VENUS
URANUS
PLUTO
MERCURY
NEPTUNE
Sct
Crt
PATH OF MOON
Crv
Hya
PsA
Cap
FLORA
VESTA
Sgr
Mic
Ant
CrA
Sco
Lup
Cen

shown for the day straight up to the curved light-blue line.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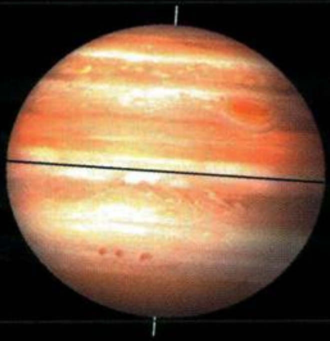
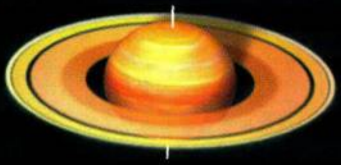
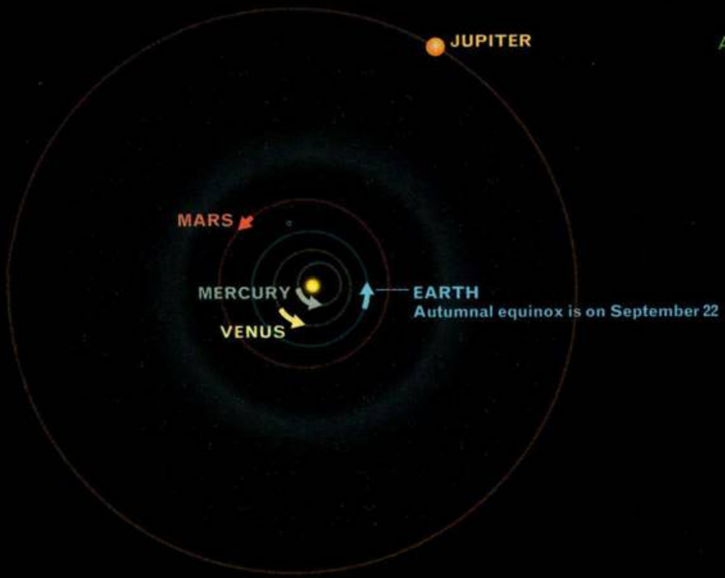


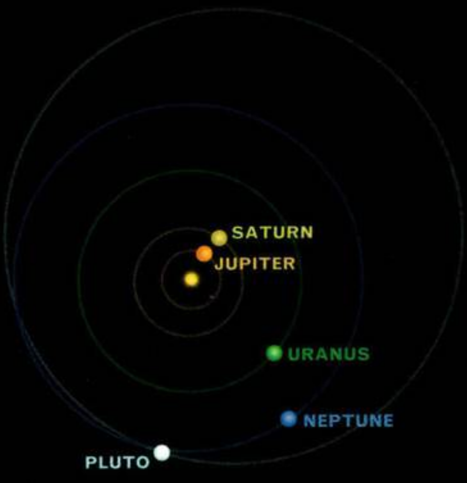


TER	SATURN	URANUS	NEPTUNE	PLUTO
ber 15	September 15	September 15	September 15	September 15
5	0.0	5.7	7.9	13.8
"	19.1"	3.7"	2.3"	0.1"
	100%	100%	100%	100%
7	8.716	19.115	29.435	30.494
6	9.132	19.948	30.112	30.302
7m	3h57.2m	21h21.0m	20h25.2m	16h41.1m
0'	18°11'	–16°16'	–19°03'	–11°24'

The Planets in Their Orbits

Arrows and dots show planets' positions during the month.


JUPITER
MARS
MERCURY
EARTH
Autumnal equinox is on September 22
VENUS


SATURN
JUPITER
URANUS
NEPTUNE
PLUTO

A Wonderful Star

Currently on show in the constellation Cetus is a variable star that changed the way astronomers look at the sky. Peaking at about 4th magnitude, Mira (Omicron [o] Ceti) is visible to the naked eye for a few weeks a year, then fades quietly into the darkness. Originally thought to be a nova, Mira reappeared 330 days later, becoming the first variable star discovered aside from the eclipsing binary "demon-star" Algol.

Medium-sized scopes will readily show its deep-orange to ruddy hue. Rising above the eastern horizon during mid-evening, Mira is well placed to observe after 11 P.M. Mira is a red giant, boasting a girth that could almost swallow Jupiter if it were put in place of the sun. In another 5 billion years, the sun will become a red giant.

The Moon Blocks Bright Stars

If you look at the map on pages 65–66, you can follow the path of the moon. This orbit slowly precesses, periodically taking the moon in front of some interesting objects. When the moon blocks light from more distant objects, the result is an occultation. This month, the moon occults three intriguing objects.

On the evening of the 6th, the bright star cluster M21 in Sagittarius dips behind the moon's dark limb. Observers in the western half of the country can witness many stars winking out and then reappearing in quick succession. To reduce the glare from the waxing gibbous moon, you'll want to use more than 100x and try to keep the lit portion of the moon out of the field. In the central time zone, start observing at 11 P.M. Toward the Rockies, be ready by 9:30 P.M. MDT, and along the Pacific coast it begins near 8:15 P.M. PDT.

On the next evening, September 7, the moon passes in front of two modestly bright stars, with little more than a 35-minute break between the events. Nu^1 and Nu^2 Sagittarii each shine at about 5th magnitude. Most of North America will be able to view these phenomena. The approximate time for the first disappearance starts at 7:15 P.M. PDT in the west and 11:50 P.M. EDT in the east. Detailed times for several locations can be found at the International Occultation Timing Association web page: lunar-occultations.com.

Taking the Milky Way's Low Road

The summer Milky Way is one of the best swaths of sky to sweep with binoculars. Gas clouds, star clouds, star clusters, and clouds of obscuring dust proliferate, making it easy to get lost.

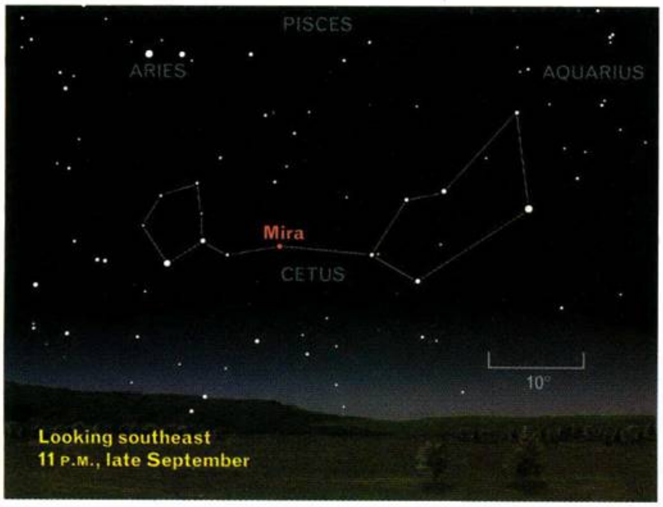
Not far from the bright Scutum star cloud and its resplendent star cluster M11 lie three large star clusters that are striking in binoculars. To reach them in the fainter branch of the Milky Way you must leap across the darkness of the Great Rift.

Aim your binoculars at Beta (β) Ophiuchi. This view should reveal a field with several bright stars accented by a large splashy cluster. If you scan too high and land on Alpha (α), the view is comparatively empty so simply sweep downward.

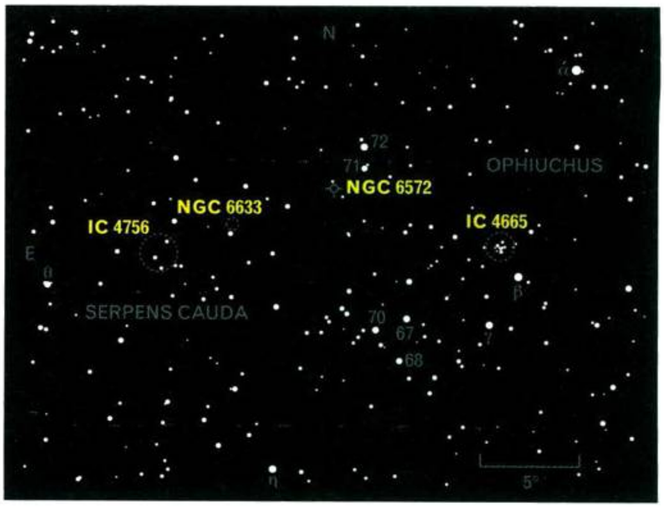
IC 4665 is the brightest *Index Catalog* object in the northern sky, perfectly suited for binoculars. Many observers in the 18th and 19th century waltzed right over it because their telescopes had too small a field of view. IC 4665 stretches more than two moonwidths, or 1°, across.

Slide two binocular fields left and you'll land on the double gem of NGC 6633 and IC 4756, both prominent star clusters. NGC 6633 is more compact and brighter. IC 4756 looks like a detached piece of the Milky Way. Any small telescope will show you their differences. One is bright and splashy, containing pairs of little stars, the other is a mound of stardust with a few sparkles shining through.

Floating just 3° west of NGC 6633 is the teal planetary nebula NGC 6572. In an 8-inch SCT, this puffball is identified by its greenish color and because it looks too bloated to be a star. It sports a diameter of about 15", roughly ⅓ the apparent size of Jupiter. To see the most green in NGC 6572, you need to stare directly at it, concentrating its light on your eye's cones. At 8th magnitude, this planetary should show color in telescopes as small as 4 inches.



Looking southeast
11 P.M., late September



The Reappearance of the Planets

In late September, **Mercury** and **Venus** appear in the evening sky shortly after sunset. Mercury will be difficult to view because it hugs the horizon even for observers at 40° north latitude. On September 23 it passes 39' north of Spica, though this 1st-magnitude star in Virgo will require binoculars to spot in the bright twilight. Mercury sets only 50 minutes after the sun on this day. Its greatest elongation from the sun occurs during the first week of October, but the planet never climbs very high above the horizon.

Venus fairs a little better than Mercury, standing 3° above the horizon an hour after sunset. However, this will only favor observers with flat, unobstructed western horizons. The visibility of Venus will not improve for some months. Venus lies low in the sky after sunset. The second planet passes 2.5° from Spica on September 19. Although Spica is a 1st-magnitude star, binoculars may be needed to spot it. The saving grace of Venus is its brilliant –3.9 magnitude.

The moon, Saturn, Jupiter, and Mars hover over Telegraph Hill in San Francisco. Timothy Ferris

From the outer reaches of the solar system the sun appears merely as a bright star. At this edge of darkness three planets, **Uranus**, **Neptune**, and **Pluto**, take decades (and in Pluto's case centuries) to orbit just once. In September's changing skies these three planets are the first to be within reach of telescopes. Pluto is the toughest planet to glimpse because it wanders among thousands of dim stars around 14th magnitude. Currently it sits near the star Zeta (ζ) Ophiuchi.

Far easier to identify is Neptune, shining at magnitude 7.9. You can find it using 7x50 binoculars as it wanders 1° west-southwest of Omicron (ο) Capricorni, a magnitude 6.7 star near the western end of Capricornus the Sea Goat. Neptune reaches a position high in the south shortly before midnight.

Brighter still, at magnitude 5.7, is Uranus. The seventh planet is easy to spot with binoculars because it lies just north of Iota (ι) Capricorni, a naked-eye star glowing at magnitude 4.2. Uranus lies exactly 40' north of Iota on September 5 and then moves westward on the following days. A scope should reveal Uranus' bluish-green, 3.7" diameter disk but no details. Neptune and Uranus are visible almost all night, setting during the early hours of morning.

Jupiter and **Saturn** rise in the late evening and reach an observable altitude after midnight. Saturn rises in the east only 20 minutes after M45, the Pleiades, and stands 6° south of that cluster. By the end of September Saturn shines at a brilliant magnitude of –0.1.

Saturn's fine system of rings appears in any telescope when using a magnification of 50x or more. The southern face of the rings tilts 24° this month, almost at the maximum. The northern pole of the planet is all but invisible, blocked from our view by the outer ring of Saturn.

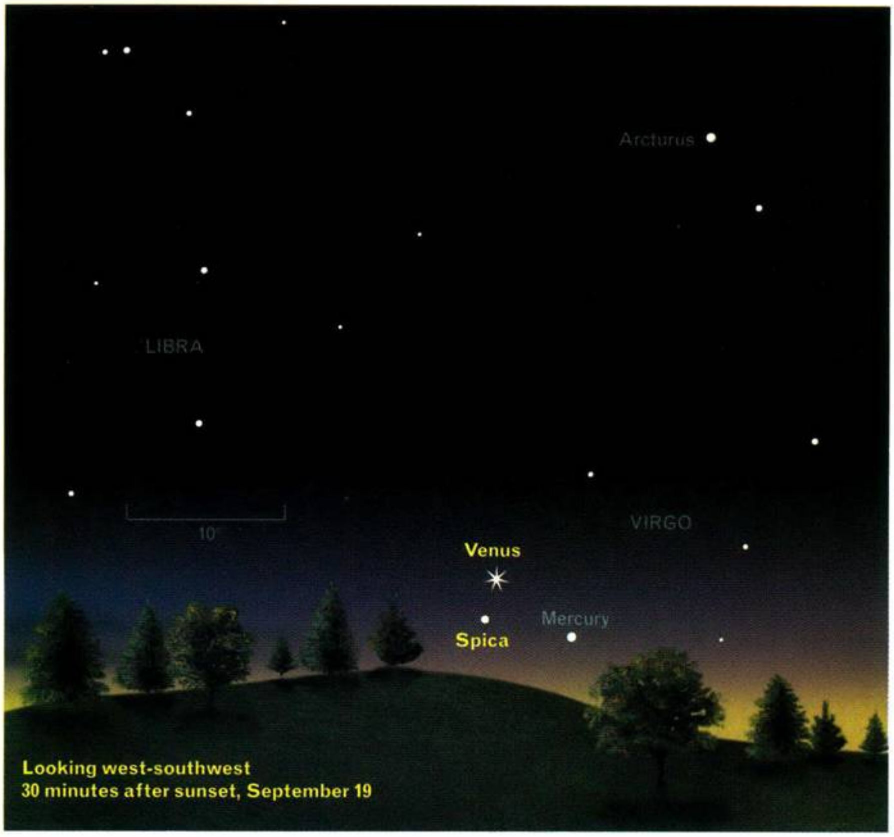
Jupiter rises 30 minutes after Saturn and is unmistakable, dazzling in its brilliant magnitude of –2.6 by September 30. Jupiter nestles perfectly among the stars of the Hyades, positioned a little under 5° north of Aldebaran, the 1st-magnitude star that marks the eye of Taurus the Bull. The spectacular setting of the brilliant planets among these attractive stars is a photographer's dream and worth recording on film. A waning gibbous moon lies 3° southeast of Saturn on the North American evening of September 18/19.

Jupiter is the largest planet in the solar system and provides a stunning view through a telescope. At opposition, which occurs in November, Jupiter spans almost 50" across — giant by planetary standards when viewed from Earth. From September onward it's larger than 40" in diameter, allowing a tremendous amount of fine detail to be observed in its upper cloud layers. Systematic observing of the light and dark areas of the jovian atmosphere soon reveals the planet's rotation. Jupiter rotates once in less than 10 hours, so in one hour more than 30° of longitude on Jupiter pass before watchful observers.

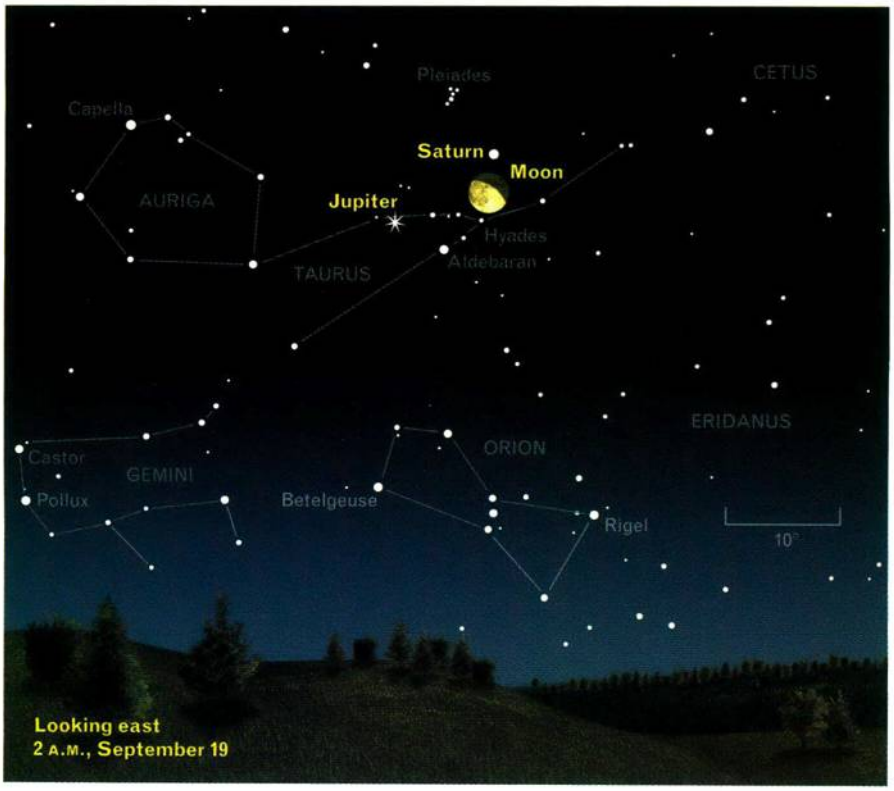
Jupiter reaches west quadrature on September 2, which to the observer means that the shadow of Jupiter that streaks behind the planet lies to its west. Watch for the Galilean satellites as they approach the western limb of Jupiter; they will plunge into the giant's shadow long before reaching the planet's limb. Notice also the soft edge of Jupiter's western limb.

The fall equinox occurs on September 22 at 12:27 P.M. Eastern Daylight Time. From now until next March, the sun will lie south of the celestial equator, signifying the approach of winter for the Northern Hemisphere and summer for the Southern Hemisphere.

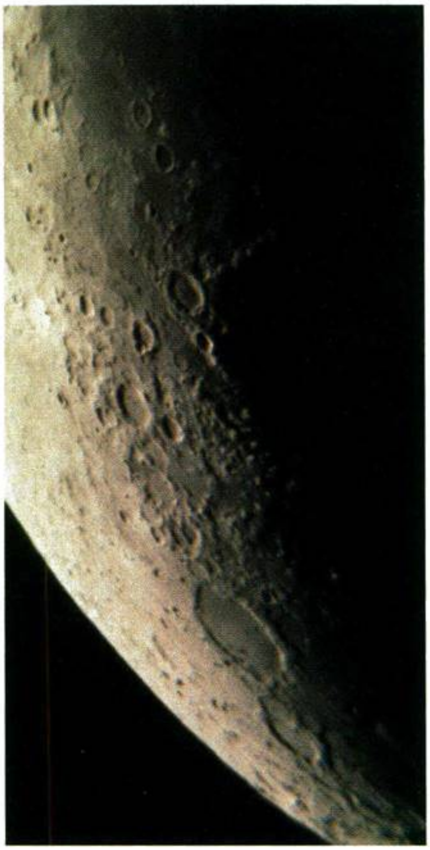
The long absent **Mars** reappears in the predawn sky, rising on September 16 some 48' north of Regulus in Leo the Lion. Mars shines a half magnitude fainter than Regulus at magnitude 1.8. Mars slowly progresses away from the sun and remains rather dim and tiny for the rest of the year.



Looking west-southwest
30 minutes after sunset, September 19



Looking east
2 A.M., September 19



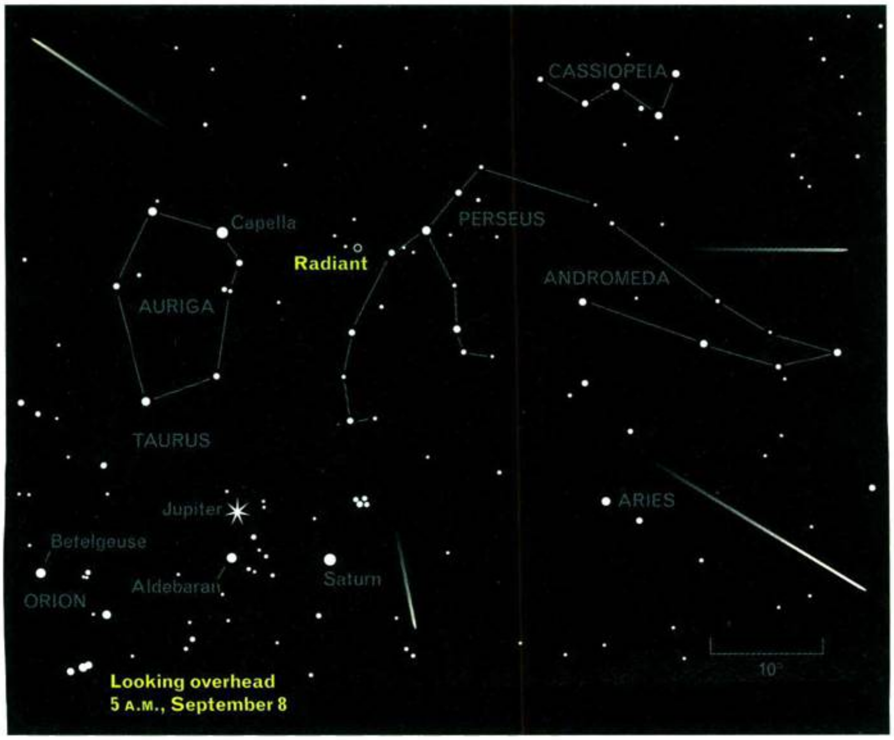
The large round structure near the bottom is the walled plain Schickard. Steve Reed

The Harvest Moon

The moon reaches its full phase on September 13 and will rise large and bright over the eastern horizon about 20 minutes after the sun sets in the west. This moon is called the Harvest Moon, a name attributed to the full moon occurring closest to the autumnal equinox. The Harvest Moon usually occurs in September but occasionally arrives in October (as it will do next year). The additional light late into the evening allows farmers to gather the harvest, hence the popular name.

Near the autumnal equinox a full moon lies in a position along the ecliptic that lies shallow relative to the horizon. This results in the moon rising only 20 to 30 minutes later each successive night instead of the typical 50 minutes between consecutive moonrises. The effect is more pronounced for latitudes farther north, and so it is not surprising that the name "Harvest Moon" originated in the northern European latitudes.

The Harvest Moon appears to loom extra large when it rises — a well-known illusion caused by its relative positioning near objects of known size, such as buildings or trees on the horizon. In fact, the moon lies slightly closer by almost the amount equivalent to the radius of Earth when it's at its highest in the sky.



The Walled Plain Schickard

A few days before full moon, the sun rises over a giant walled plain in the southwestern quadrant of the moon. The plain is large enough, 150 miles across, that its shape follows the curvature of the moon's surface. However, the central region of the crater is raised an additional 700 feet and appears lighter in shade than the northwestern and southeastern ends of the plain that have been flooded with lava. It lies close to the moon's southwestern limb, so typically it's highly foreshortened.

During September, however, the libration of the moon is such that Schickard can be viewed more easily than usual. Libration is a gentle rocking of the moon allowing us to see, over a month, more than 50 percent of the moon's surface. Caused by the moon's slightly oblate orbital path, libration can vary the moon's angle to us by up to 10° — and by mid-September reaches 8.2° in the northwestern quadrant, partially aiding the view of Schickard to the south.

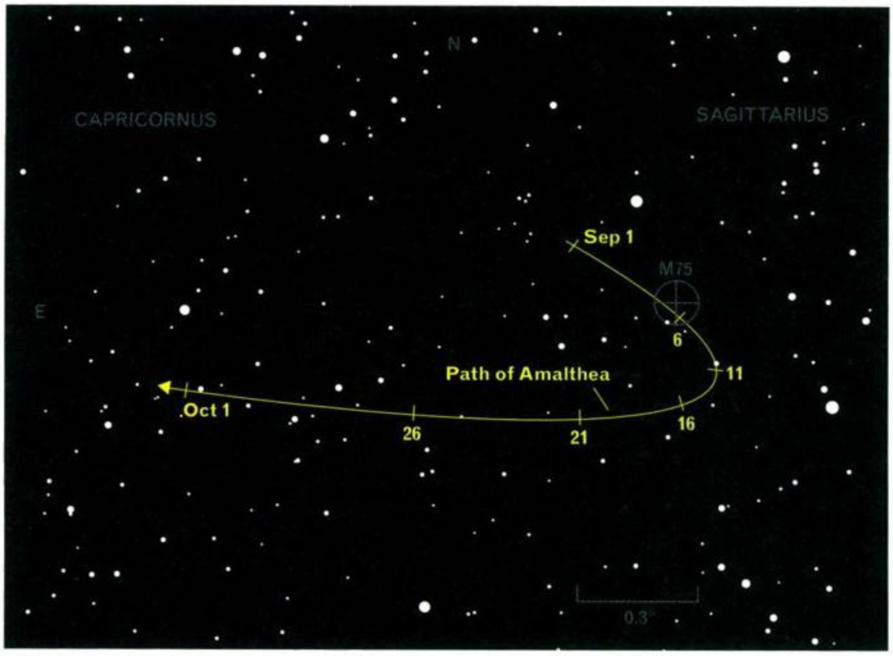
Try making a pencil sketch of the area as a record of what you see. How many craters can you detect on the floor of the giant plain? Also notice, southeast of Schickard, three overlapping walled plains. They are, from north to south, Wargentin, Nasmyth, and Phocylides. Catching sunrise on these areas is dramatic because the appearance of sunlight as it falls on the walls of these plains changes over a period of 30 minutes or so. Sunrise over this region will occur on September 10, so watch the moon rise on this evening to catch the first rays of the sun hitting the floor of Schickard. Check the feature throughout the night as its appearance changes.

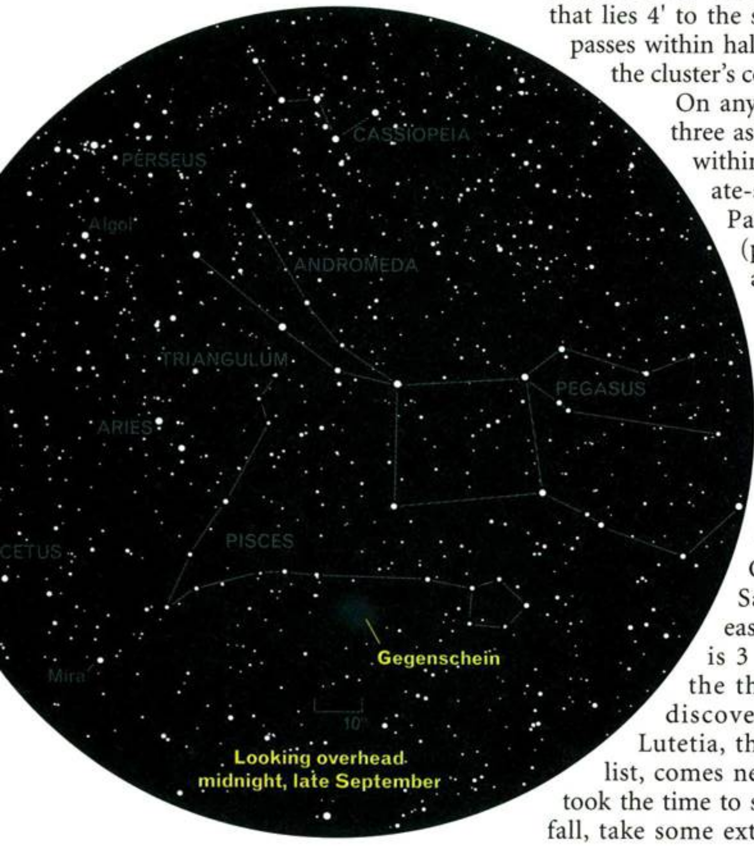
Minor Meteors

September can never compete with August for meteors, but it does have the persistent rain of sporadic meteors, plus a notable minor shower. The Delta Aurigids meteor shower peaks around September 8. The rate is expected to be about six meteors per hour. This year the waxing gibbous moon sets as the radiant in Auriga rises — a favorable situation. By dawn the radiant is practically overhead, giving the best chance for viewing members of the shower during early morning hours. The occasional bright meteor may leave a persistent train, but generally the shower produces faint and swift trails. (See the radiant map on page 72.)

An Asteroid Roundup

On the evening of the 5th and 6th, the modestly sized asteroid 113 Amalthea grazes the southeastern flank of the bright globular cluster M75. At a magnitude of 12.4, Amalthea will be handily brighter than the individual distant supergiant stars of M75. Don't mistake it for the 11.6-magnitude star that lies 4' to the southeast. Amalthea passes within half of that distance of the cluster's core.





On any given night two to three asteroids are normally within reach of a moderate-sized telescope. The Path of the Planets (pages 65 – 66) tracks a number of them every month. In mid-September, five 9th-magnitude asteroids drift near the ecliptic. Starting in the west, asteroid 8 Flora dances along the border between Capricornus and Sagittarius. Further east and a bit brighter is 3 Juno in Aquarius, the third asteroid to be discovered. Asteroid 21 Lutetia, the dimmest on our list, comes next in Cetus. If you took the time to search out Mira this fall, take some extra minutes to pinpoint Lutetia. Rising above the eastern horizon later in September are the constellations Aries and Perseus, which tote asteroids 192 Nausikaa and 324 Bamberga, respectively.

Gegenschein

The hours of midnight from late September to early November provide the perfect time to locate the ever-elusive gegenschein. The German word means "counterglow." The gegenschein results when sunlight reflects from zodiacal dust particles at the position opposite the sun in the sky, or the "antisolar point." But instead of a pyramid shape like the zodiacal light, the gegenschein consists of a faint, oval glow 10° across found most easily when it is near the zenith, which will be in the vicinity of Pisces this autumn. Seeing the gegenschein requires very dark skies: Moonlight, too many bright stars, or even the light from the Milky Way can ruin your opportunity to see it. Use the map at left to help in detecting it. ■

Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.

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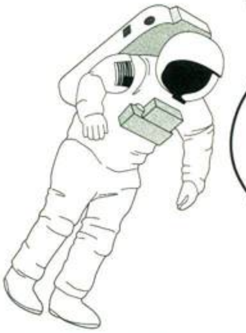

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Exploring the Digital Darkroom

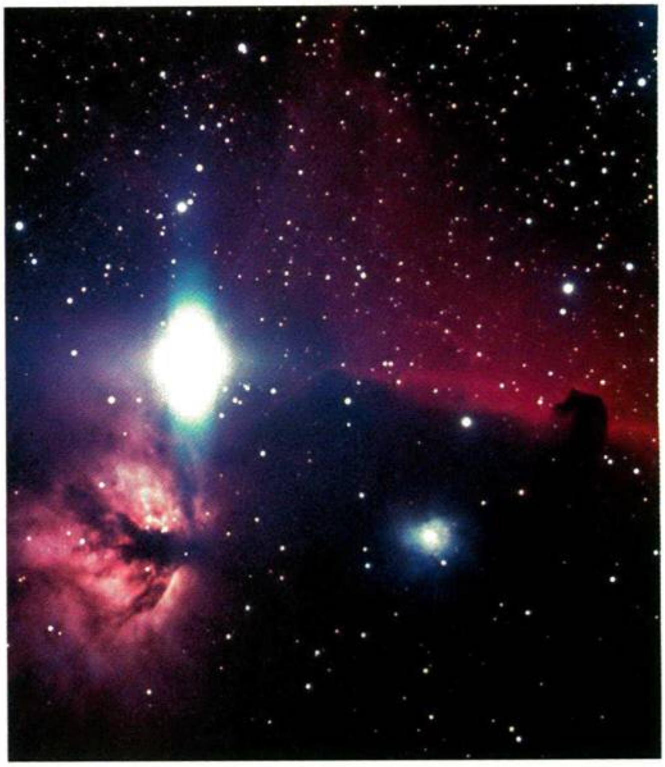
The final steps in digital imaging reveal tricks of the computer processing trade.

by Gregory Terrance

When you think of a darkroom, images of red safelights and strips of drying film probably come to mind. While these were once the trappings of darkrooms, now image processing is increasingly confined to the desktop computer, at least for images captured by CCDs. Lackluster raw images can be transformed into spectacular celestial portraits with a series of mouse clicks rather than hours of darkroom work. If you plan to use a digital darkroom, you'll need more than just raw astroimages. As a CCD camera grabs an image, it also captures noise and artifacts caused by optical problems. Fortunately these defects can be minimized or eliminated through a process called image calibration.

The North America Nebula shines in an image made with a 6-inch f/7 refractor and ST-8 camera. Robert Gendler

Nebulosity around Merope in the Pleiades shot with a 12½-inch Cassegrain-Newtonian scope and an IMG1001E camera. Brian Lula



Objects such as the Horsehead Nebula environs can be effectively shot with a CCD; this is a 6-inch f/7 refractor and ST-8 image. Robert Gendler

Each raw image (planet, nebula, or galaxy that you've captured) requires taking a flat field and a dark frame image to cure these digital defects. In addition, the flat-field image itself needs a dark frame — totaling three files required for calibration. (That's a minimum; some advanced image calibration techniques use 24 or more images.) The best time to grab these images is just before or after you've snapped a celestial object with your digital camera. Without image calibration, optical and electrical defects in your raw image will be emphasized during image processing, degrading the final image.

A raw exposure contains something called dark current noise that makes the image look speckled and grainy, similar in appearance to photographs taken with superfast film. The first step in eliminating this effect is to take a dark frame. This is simply an exposure, equal in length to the raw image, taken with the shutter of the camera closed. With no light falling upon the CCD during the exposure, only noise generated by the CCD itself is captured. A dark frame uses the same exposure and temperature settings as the raw image did. (Dark current growth is directly linked to time and temperature.) With a dark frame exposure in hand, you can subtract dark current noise from the raw image using software supplied by the camera manufacturer. The resulting image is considered to be "dark frame subtracted" and is ready for the next step of calibration, flat-field correction.

A flat-field image is a CCD exposure of a uniformly illuminated object such as the early evening sky, a large white card, or a specially designed light box that fits over the end of the telescope. These exposures capture the same optical defects that are contained in the raw image (such as uneven illumination from the telescope, dust particle shadows, and pixel sensitivity variations). Since only optical defects are captured during a flat-field exposure, they are the only things removed from the file that you're trying to clean up. In essence, you can think of a flat-field image as a digital squeegee that wipes a raw image clean, leaving it ready for processing.

Unlike a dark frame, a flat field must be taken with the camera in the same position as the original raw image (this includes its rotational orientation as well as focus). That's because optical defects are usually tied to the camera's location. If you move the camera relative to the optical defects, you'll end up removing defects from the raw image where they don't exist.

In addition, because a flat-field exposure also builds up dark current noise, a dark frame must be taken and then subtracted from the flat field prior to using it. The temperature and exposure of this dark frame must match that of the flat field, not the raw image. Once you have subtracted a dark frame from your flat-field image, that result can be used with the "dark frame subtracted raw" image for flat fielding using the CCD camera software. With that accomplished, your original raw image will finally be ready for the image processing stage.

Processing the Images

From an astronomical point of view, four types of software packages offer image processing help. If you're already taking CCD images, you have the most basic of these; the software supplied with the CCD camera itself. For the most part, CCD camera software is primarily concerned with image acquisition, image calibration, and file conversion (so the native camera files can be read by image editing software and by Internet browsers). Unfortunately, that leaves image processing a distant consideration.

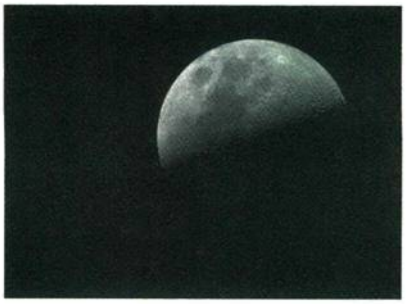
NOT JUST ANY OLD IMAGE

Successful CCD imaging doesn't result from just going out and shooting a single image. The spectacular results you see from digital imagers in this magazine result from a sequence of images artfully combined into a final product. Such craftsmanship is necessary because of defects inherent in the optical and electrical systems of CCD and telescope equipment.

Three images must be made for each planned final shot — a raw image, a dark frame, and a flat-field frame. Only through careful coordination and image processing as seen below can near-perfect images of planets and deep-sky objects appear in the end result. The culprits requiring this fussiness are electrical dark current noise, uneven field illumination across the chip, dust in the system, and other gremlins.

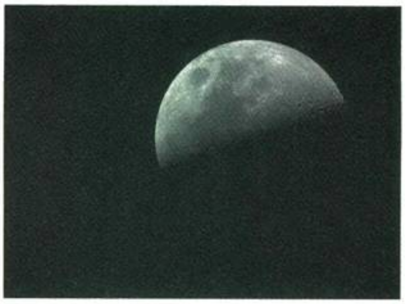
Though shooting dark and flat-field frames may at first seem laborious, a little practice will turn you into a pro. — *Dave Eicher*

STEP ONE



Once you've taken a raw image, you need to rid yourself of inherent defects.

You do so by making a dark frame, which records the system noise.

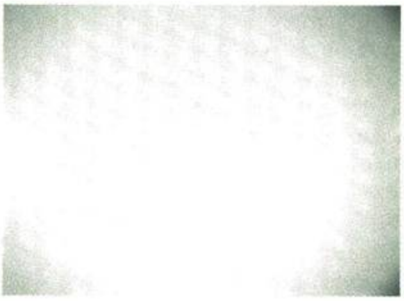


Subtracting the dark frame from the raw image yields a dark subtracted raw image.

STEP TWO

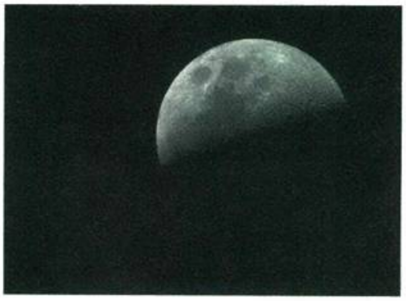
Next, make a flat-field image by exposing an even field such as bright sky.

Then take flat-field dark frame.

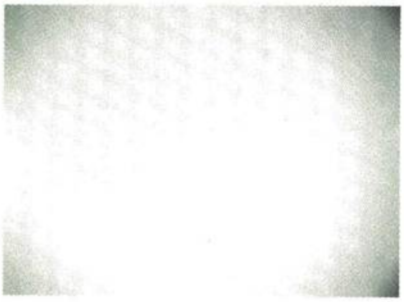


Subtracting the dark frame provides a dark frame subtracted flat field.

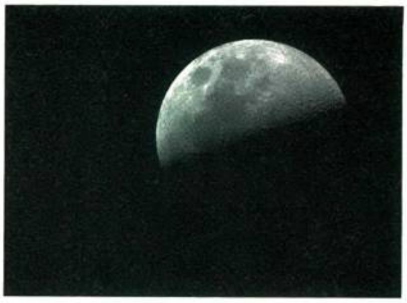
STEP THREE



Final correction begins with the dark frame subtracted raw image.



Next, employ the dark frame subtracted flat-field image.



By subtracting the flat-field from the subtracted raw, a final image results.

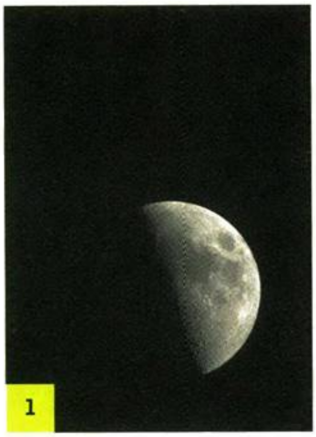
DARKROOM IN A BOX

Gone are the days when astroimagers pulled out trays of stinky chemical developers, stop bath, and fixers and set them around the pitch-black bathroom in the middle of the night. The morning's result may have included superb dried prints hanging from the shower curtain, but it also made the whole place smell like the inside of a petroleum refining plant.

Now astroimagers have all the power of a conventional darkroom — and more — inside their desktop computers. Given a calibrated image, desktop software now allow a vast range of image manipulations with just a few mouse clicks.

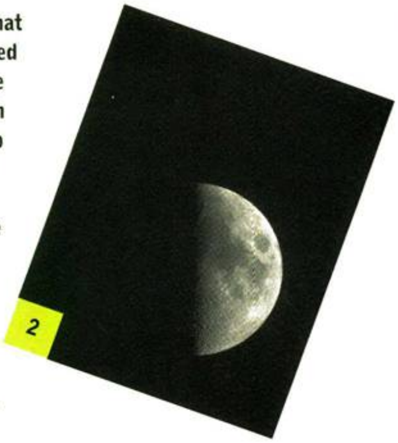
Not only can you reorient, zoom in, and refine your image by boosting its contrast or enhancing the tonal range of its pixels, but you can instantly get results and send them to friends or magazines across the Internet. Take care not to overprocess so that your images stay true to what you recorded in the first place. *— D.E.*

1) Once you have a calibrated image (one that's dark frame subtracted and flat fielded), you're ready for the exciting world of image processing.



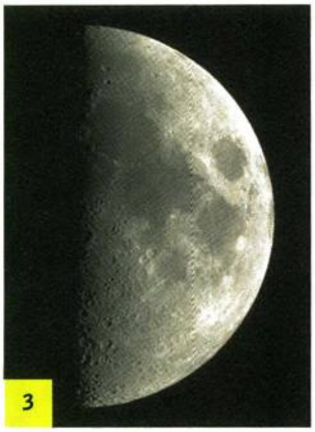
1

2) Frequently you'll find that a CCD image is not oriented as you might want it in the final image. Software such as Photoshop allows you to rotate the image; strange frame orientation can be solved by cropping. Rotate the image all at once, not in increments. Every time a transformation (rotation, scaling, skewing, etc.) is made, information is lost.



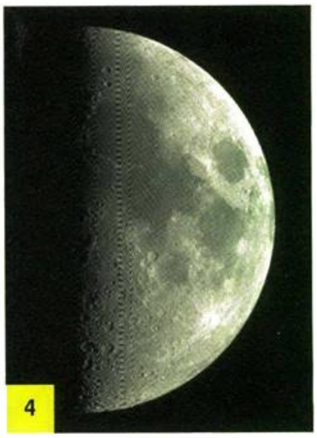
2

3) Cropping an image creatively removes unneeded areas such as swaths of dull black sky. This provides a centered, balanced look. The files size also shrinks, which makes storing the images easier and reduces downloading times if you're sending them via the Internet.



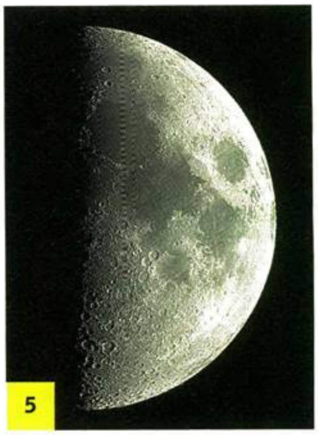
3

4) Now the real processing: snap, crackle, and pop can be added to the images by adjusting levels, brightness, and contrast. You can make the background darker, the highlights whiter, and the midtones fuller. Most image processing software has many ways to adjust brightness, contrast, saturation, and color balance.



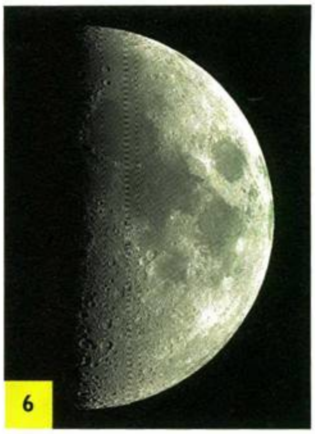
4

5) Final processing often comes with sharpening an image, which snaps detail into razorlike crispness. Be careful not to oversharpen, as with this image, because the result will be gritty and off-putting.



5

6) Sharpening tools are highly effective for lunar and planetary images where pixel contrast is critical. Sharpening also highlights noise, so use it carefully. It is sophisticated enough to require lots of experimentation to get your results just right.



6

Image processing allows you to stitch together images to cover a wide field, as with this mosaic of the Virgo Cluster. Robert Gendler

Careful processing brings out previously hidden details in large galaxies such as the emission nebulae ringing M83's spiral arms. Jack Newton

Ultimately you'll want a more powerful program to process your images. A number of options specifically target astronomical digital imaging. Some of the better known names include Maxim DL, Superfix, Megafix, and QmiPs. Prices range from $280 for Maxim DL to cost-free for QmiPs, which can be downloaded via the Internet. These programs have advanced features such as tricolor assembly, planetary coadding, sophisticated sharpening tools, file management, and specific CCD camera file format support. However, they cannot acquire CCD images or operate the CCD camera. That forces you to use two programs.

To combat this issue, a few savvy software companies have designed a new breed of software. Taking a twist on astronomy-specific programs, they've designed software for astroimagers that uses one program for both image acquisition and processing. This class of software can control CCD cameras from different camera manufacturers (see "Capture the Sky on a CCD," February 2000) as well as post-process images with advanced techniques. They also simplify the long and laborious calibration process by using automated calibration schemes, saving time and effort. Two of the best all-in-one programs are Maxim DLCCD and Astroart.

Finally, software designed for photographers and web designers works well for processing digital astroimages. Adobe Photoshop currently is considered to be the number one contender. The current version, 5.5, includes a reversible history selection, batch processing, specialized Internet functions, and many more powerful tools. Others to consider include Picture Publisher, Corel Photo-Paint, and a cost-free new arrival called The GIMP — a Linux program. The biggest drawback of any of these programs is the fact that they generally will not process 16-bit images, particularly 16-bit FITS images (the choice of professional astronomers).

Regardless of which program you use, image processing can dramatically improve your digital images. Raw images of celestial objects usually appear dull and low in contrast, but they actually possess a surprising amount of information that can be accessed and utilized. You don't need to jump into advanced techniques to get great results; basic image processing can substantially improve an image's appearance without fancy filters or sophisticated algorithms. Experimentation will guide you to the most appropriate method of what will work best for any given image. In time you'll develop a standard set of procedures to work from as a springboard for more elaborate changes.

As an astronomer, you can expect to encounter objects that vary greatly in size, brightness, and contrast, far more than with family or landscape photographers. Initially, try adjusting the fundamental aspects of an object: its orientation, frame size, contrast, brightness, and sharpness. If you choose to go beyond these, an almost unlimited number of processing techniques can be considered. The most common pitfall to avoid is overprocessing, which results in harsh, artificial-looking results and does not accurately portray what we could see with the human eye.

To produce a great finished product you need to start with good raw images — as powerful as it is, image processing will not correct for guiding errors, improper focusing, or inadequate exposures. The power of digital imaging lies in the ability to remove defects and enhance the appearance of the galaxies or planets you're shooting. The current software make your images shine by showing every bit of information you record from the sky. ◼

Gregory Terrance is an active CCD imager who lives in New York.

Pegasus & Equuleus

Artwork at left from *The Glorious Constellations*, © 1991; Harry N. Abrams, Inc.

A multitude of galaxies and one glorious globular cluster highlight this pair of celestial horses.

by Tom Polakis

AS THE RICH STAR FIELDS AND magnificent nebulae of the summer Milky Way sink toward the western horizon, the more subtle beauty of the autumn sky takes center stage. At this time of year, our view reaches well beyond the confines of our own galaxy to the myriad galaxies that pervade the cosmos.

Even the star patterns visible in autumn pale in comparison to those in the splashy summer sky. Perhaps the most recognizable of these asterisms passes nearly overhead as seen from mid-northern latitudes. The Great Square of Pegasus consists of four bright stars that form the body and wings of the mythological Winged Horse. Unfortunately, few people can see the rest of the equine's shape in its stars. One of the least significant constellations precedes Pegasus to the meridian. Equuleus the Little Horse contains two 4th-magnitude stars and three 5th-magnitude stars, making the sky's second smallest constellation easy to overlook.

Not so with the Great Square, a fine naked-eye asterism anyone can find. At first glance, the four stars may seem to have the same brightness, but a closer look shows the brightest star gleaming twice as brightly as the dimmest. Oddly enough, the Square's brightest star doesn't officially belong to Pegasus. Alpha (α) Andromedae, shining at magnitude 2.1, marks the northeastern corner of the Square. Until the 1930s, it belonged to two constellations and also went by the name Delta Pegasi. Beta (β) Pegasi, a red giant star whose color contrasts nicely with the blue-white hue of the three other stars, stands at the northwestern corner of the Square. A nonmember of the Great Square completes the list of bright stars in Pegasus. Enif (Epsilon [ε] Pegasi) lies 30° west of the giant asterism's center and represents the nose of the great horse. This ruddy beacon shines with the light of 4,000 suns from nearly 700 light-years away.

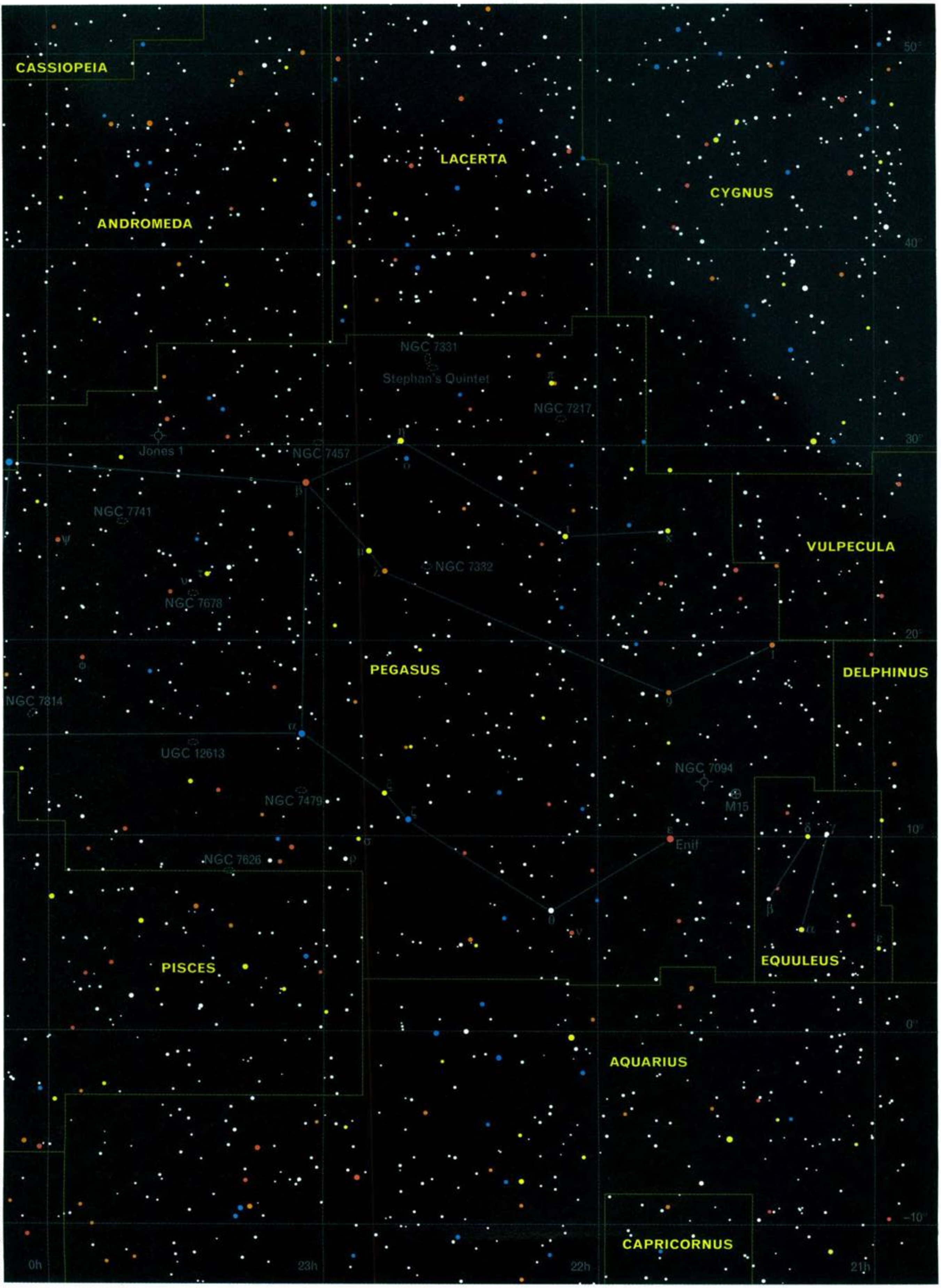
Our telescopic tour of the two horses begins in unassuming Equuleus. Although it contains no galaxies, clusters, or nebulae of interest, the Little Horse can claim several nice double stars. Perhaps the best is **Epsilon Equulei**, an easy split at 30x in any telescope. The colors — slightly different shades of yellow — become more apparent with increasing aperture. On a steady night with an excellent instrument, the primary resolves into a close pair. All three stars belong to the same system, with the more distant star orbiting the closer binary system.

The showpiece globular cluster of the autumn sky lies in far western Pegasus. You can locate **M15** (NGC 7078) by projecting a line from Theta (θ) Pegasi through Enif and extending it about 50 percent farther. At magnitude 6.0, M15 can be glimpsed with the naked eye on a good night, but an equally bright star just 0.3° to the east easily confuses the identification. The cluster appears unmistakably fuzzy with any magnification. Hundreds of stars glow brightly enough to be resolved in a small telescope at medium magnification despite the cluster's distance of 34,000 light-years.

Yet the most impressive aspect of M15 has to be its remarkably intense core and the star chains that seem to emanate from it. Even on near-perfect

M15

Bill Iburg


CASSIOPEIA
LACERTA
CYGNUS
ANDROMEDA
NGC 7331
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NGC 7217
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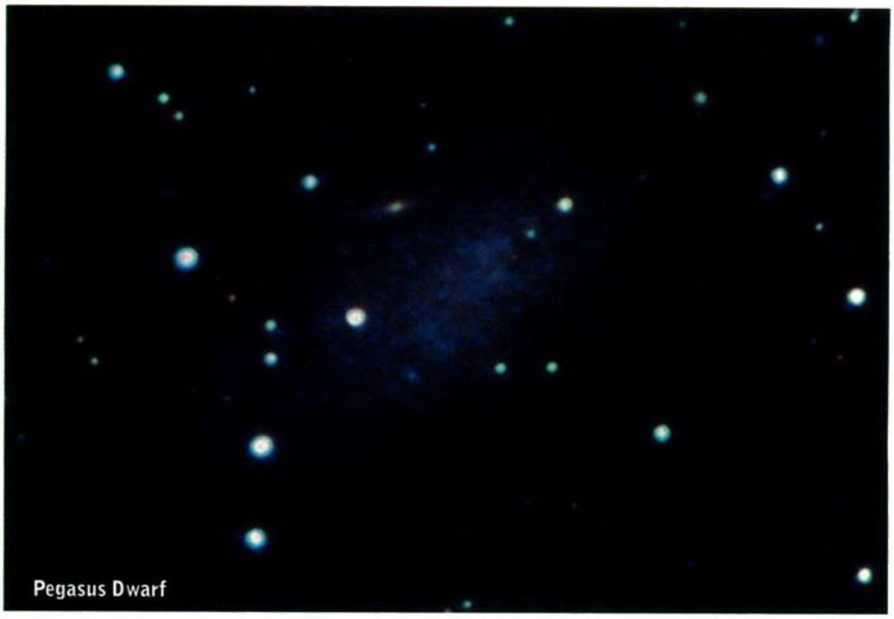
Astronomy: Elisabeth Rowan



Pegasus Dwarf

James Foster

nights with large telescopes, this central blaze is so packed with stars that it appears as an unresolved, gleaming disk. In this respect, I consider M15 the northern sky's best analog to 47 Tucanae, which has the most stunning central region of any globular.

A planetary nebula near the center of M15 makes the cluster even more exotic. Astronomers know of only four globulars containing a planetary and two of those lie well beyond the reach of backyard telescopes. Francis Pease discovered **Pease 1** in 1928 when he noticed a "star" that appeared unusually bright on a photographic plate taken through an ultraviolet filter with the 100-inch Hooker Telescope on Mount Wilson. Spectra of the object showed the characteristic emission of a planetary nebula. Today an observer can spy Pease 1 with a 10-inch telescope and a nebula filter, which suppresses the stars and makes the planetary appear brighter. Pease 1 lies in a crowded star field about 1' northeast of M15's core.

A pan 2° east-northeast of M15 lands the telescope on a more visible planetary nebula, **NGC 7094**. An 8-inch telescope barely shows it as a gray disk measuring 1' across, though it becomes more evident when viewed through a nebula filter. A 13-inch scope brings the 14th-magnitude central star into view and shows hints of annularity in the nebula. Through a 20-inch instrument, the ring appears obvious and broken on both the north and south edges.

Just 3° south of Alpha Pegasi, the star at the southwestern corner of the Great Square, lies the galaxy **NGC 7479**. Even at a distance of 130 million light-years, this galaxy ranks as a showpiece because of its peculiar form. A 10-inch telescope clearly shows the oddly shaped spiral structure. On first impression, the galaxy shows a bright core, surrounding central bulge, and a bar elongated north to south. Further scrutiny begins to reveal a single, tightly wound spiral arm curling to the west of the south end of the bar. The north end of the bar ends just shy of a

Deep-Sky Objects in Pegasus and Equuleus

Object	R. A. (2000.0)	Dec.	Mag.	Size/Sep.	Type	Notes
NGC 7814	0h03.3m	16°09'	10.6	6.0' by 2.5'	Gal	SA(s)ab
Epsilon Equulei	20h59.1m	4°18'	6.0/7.1	10.7"	Dbl	
M15 (NGC 7078)	21h30.0m	12°10'	6.0	12.3'	GC	
Pease 1	21h30.0m	12°10'	15.5	3"	PN	
NGC 7094	21h36.9m	12°47'	13.4	94"	PN	
NGC 7217	22h07.9m	31°22'	10.1	3.5' by 3.1'	Gal	(R)SA(r)ab
Stephan's Quintet	22h36.0m	33°58'	—	—	Gals	
NGC 7331	22h37.1m	34°25'	9.5	10.5' by 3.7'	Gal	SA(s)b
NGC 7332	22h37.4m	23°48'	11.1	3.7' by 1.0'	Gal	S0 pec
NGC 7457	23h01.0m	30°09'	11.2	4.1' by 2.5'	Gal	SA(rs)
NGC 7479	23h04.9m	12°19'	10.8	4.0' by 3.1'	Gal	SB(s)c
NGC 7626	23h20.7m	8°13'	11.1	2.4' by 1.9'	Gal	E pec
NGC 7678	23h28.5m	22°25'	11.3	2.3' by 1.7'	Gal	SAB(rs)c
UGC 12613	23h28.6m	14°45'	12.6	4.6' by 2.8'	Gal	Im V, Pegasus Dwarf
Jones 1	23h35.9m	30°28'	12.1	332"	PN	PK 104–29.1
NGC 7741	23h43.9m	26°05'	11.3	4.0' by 2.7'	Gal	SB(s)cd

Object: Designation in Messier, NGC, or other catalog. **R. A. (2000.0) and Dec.:** Right ascension and declination in epoch 2000.0 coordinates. **Mag.:** Visual magnitude. **Size/Sep.:** Size in arcminutes or arcseconds; separation in arcseconds. **Notes:** Hubble type for galaxies.

The Winged Horse

"And vaulted with such ease into his seat,
As if an angel dropped down from the clouds,
To turn and wind a fiery Pegasus,
And witch the world with noble horsemanship."
Henry IV
William Shakespeare (1564–1616)

Most of the ancient constellations represent some extraordinary creature or god but are depicted in the heavens in fairly ordinary ways. So while you may not find a dragon or centaur on a trip to the local zoo, Draco and Centaurus appear as rather run-of-the-mill creatures in the sky. And there's nothing terribly odd about how Leo the Lion or Scorpius the Scorpion are represented either.

The same can't be said for Pegasus the Winged Horse, which possesses a trio of strange characteristics. Most obviously, Pegasus has wings and can fly. Add to that that the horse is never shown with hindquarters or a tail. Finally, Pegasus wings its way across the sky upside down, with its head down and legs above its body.

Pegasus plays a role in one of the more famous Greek myths, which also involves several of Pegasus's celestial neighbors. Andromeda was the daughter of King Cepheus and Queen Cassiopeia, who often boasted of her beauty. This so angered the maidens who attended Poseidon, the god of the sea, that they demanded he punish the queen. So he sent the sea monster Cetus to terrorize Cassiopeia's realm. Cepheus asked an oracle how to stop the monster and was told to sacrifice his daughter to the monster by chaining her to a rocky island.

Enter the story's hero, Perseus. He had just slayed the Gorgon Medusa, who was so ugly that a mere glance at her face turned a person to stone. Perseus mounted Pegasus, who Poseidon created out of white sand, sea foam, and blood from Medusa's severed head. Perseus saw Andromeda in trouble and swooped down, showing Medusa's head to Cetus and turning it to stone. Of course, Perseus and Andromeda immediately fell in love, got married, and lived happily ever after. — *Richard Talcott*

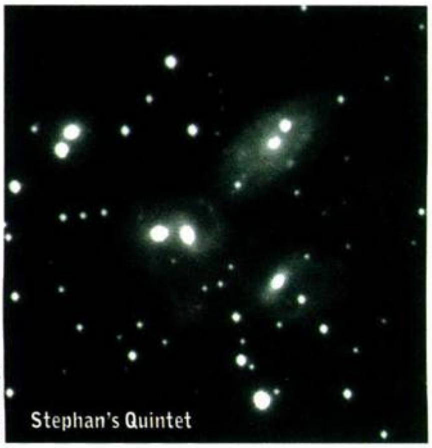
13th-magnitude star, but no trace of a spiral arm can be seen on this side. Increasing the aperture to 20 inches exposes a large, hazy envelope surrounding the galaxy, but I still couldn't see this spiral arm, which appears faintly in photographs.

Along the southern leg of the Great Square lies the **Pegasus Dwarf** (UGC 12613), one of the most distant members of our Local Group of galaxies. At a distance of 5.7 million light-years, this dwarf irregular appears in a 10-inch scope as a dim mist twice as long as it is wide. A dark sky and ample patience will be needed to spot this outlying member of our galactic neighborhood.

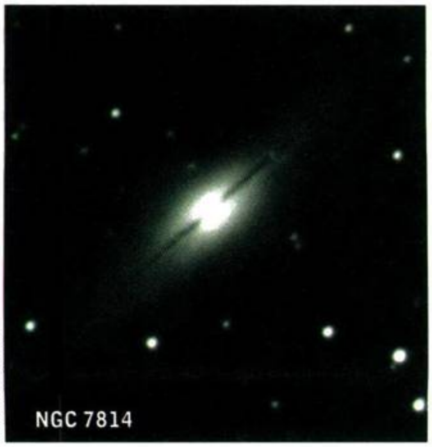
Head 7° south to find the giant elliptical galaxy **NGC 7626**. It and its near twin, NGC 7619, which lies just 7' to the west, are the brightest members of the Pegasus I galaxy cluster. Despite being nearly 200 million light-years away, the two appear quite bright. A medium-aperture telescope shows each galaxy as a bright core immersed in a featureless halo about 2' across. NGC 7626 looks oval, while NGC 7619 appears nearly round.

Three degrees west-northwest of Gamma (γ) Pegasi lies the fabulous edge-on spiral galaxy **NGC 7814**. Photographs reveal a pencil-thin dust lane that proves elusive through the eyepiece but satisfying once you spot it. A large scope at a dark site shows the dust lane only in the innermost regions. Even without this ribbon of dust, NGC 7814 looks magnificent, presenting a large and uniformly bright central bulge with wings that extend the dimensions to 5' by 2'. The view gives the correct impression that we reside in the equatorial plane of this galaxy, which lies 60 million light-years away.

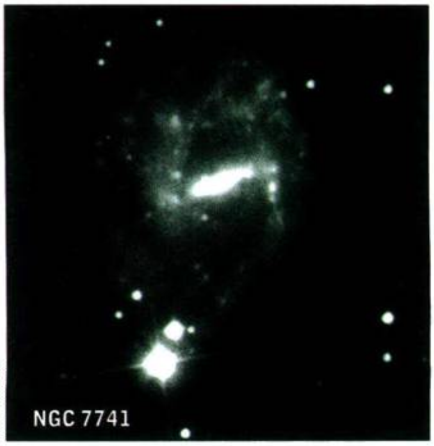
The center of the Great Square harbors the small but detailed galaxy **NGC 7678**. This face-on spiral displays a sharp, stellar nucleus and a halo no larger than 2' in diameter. A 13-inch telescope brings out a ring of spiral structure in the immediate vicinity of


Chuck Vaughn

Stephan's Quintet


Martin C. Germano

NGC 7814


Kim Zussman

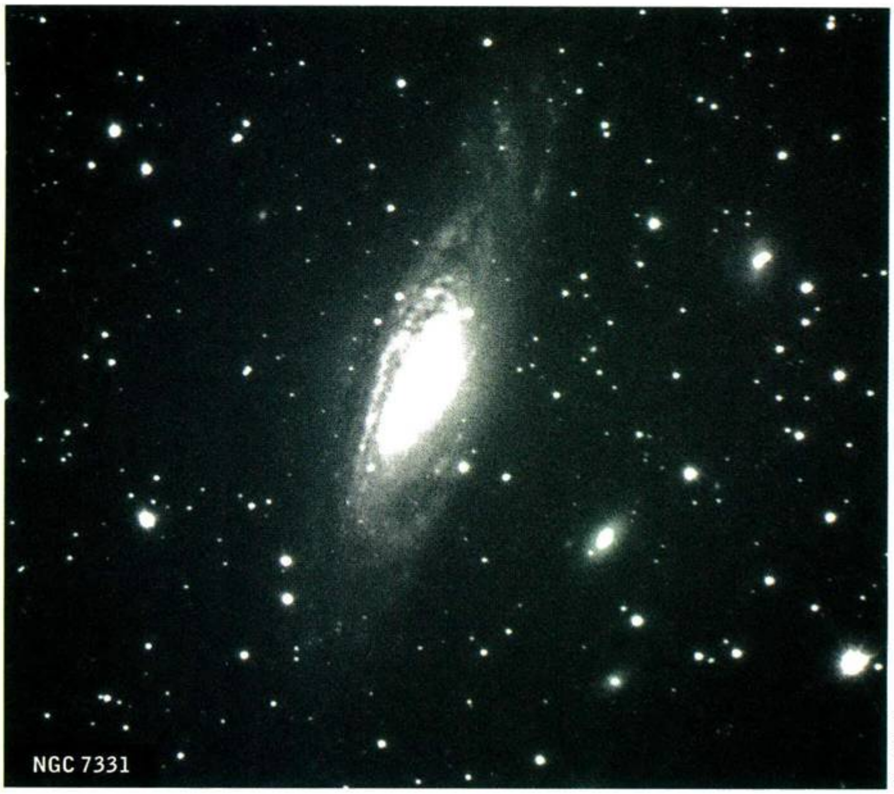
NGC 7741

the core. A tight isosceles triangle of 12th-magnitude stars nicely frames the entire object.

The ring galaxy **NGC 7217** lurks in northwestern Pegasus, some 2° south of the 4th-magnitude star Pi (π) Pegasi. Images taken with professional telescopes reveal three concentric rings surrounding a nearly stellar core, though you'll be hard pressed to make out any detail across the 60 million light-years that separate us. The galaxy shows up nicely in an 8-inch telescope, with a very bright center immersed in a halo that appears cometary. Unfortunately, it refuses to yield detail in larger apertures. Even with a 20-inch scope, I could not see the outer ring that gives NGC 7217 its classification.

Projecting a line from Mu (μ) through Eta (η) Pegasi will bring you to the impressive galaxy **NGC 7331**. This spiral belongs to a galaxy group about 50 million light-years away that includes 8 to 10 faint members, all of which lie outside the telescopic field of view. A low-power eyepiece will disclose three galaxies to the east that form an equilateral triangle, but they all lie well in the background and are not companions. A 10-inch telescope shows NGC 7331 as a bright oval three times as long as it is wide. Inside this haze, a bright, inner bar contains the galaxy's gleaming stellar core. Larger scopes show that the western edge ends abruptly at a dust lane and, on the best nights, a spiral arm shining beyond this lane.

Use NGC 7331 as a starting point for locating **Stephan's Quintet**, a collection of five galaxies just half a degree to the southwest. A 6-inch scope at 50x shows them as a clumpy glow covering an area 3' across. You'll need a large-scale photograph or chart and 12 inches of aperture to identify the individual members. The southwestern edge of Stephan's Quintet is marked by NGC 7317, which lies next to a 13th-magnitude foreground star. Pan 2' east to find NGC 7318A and B, two galaxies that often appear as one merged object. The brightest and largest member of the group, NGC 7320, lies to the southeast and contains a 13th-magnitude foreground star in its halo. NGC 7319 ranks as the most difficult galaxy in the group, a dim smudge at the northeastern edge of the quintet. None of these galaxies spans more than 2', so use high magnifications to view them best.


NGC 7331

Chuck Vaughn

Stephan's Quintet proves that appearances can be deceiving. Certainly the eyepiece impression is of a tight galaxy group, but one of them surely does not belong to the club. Four qualify as great galaxies lying at a distance of roughly 300 million light-years, but the dwarf galaxy NGC 7320 resides in the foreground just a tenth as far away.

NGC 7332 teams up with NGC 7339 to form a gorgeous pair of elongated galaxies just 2° west of Lambda (λ) Pegasi. NGC 7332 measures 4' by 1' and shows a classic lenticular, or lens-shaped, form surrounding a bright core. NGC 7339 shows a broader center and measures five times longer than it is wide. It appears fainter and does not have the lens shape of its neighbor 5' to the west.

The nearby spiral galaxy **NGC 7457** dwells 2° north-northwest of Beta Pegasi. Its main claim to fame is an extremely small, dense core, second to only M32 among known galaxies. Telescopically, this aspect shows up as a bright center surrounded by a faint oval haze.

Slightly north of the northern side of the Great Square, **Jones 1** seems like an out-of-place planetary nebula. Most planetaries lie close to the plane of the Milky Way, but this one finds itself a full 30° away. At a distance of 2,000 light-years from Earth, it appears in a telescope as a ghostly haze some 5' across. My 8-inch scope barely shows it, and only with the aid of a nebula filter. In a 13 inch, it begins to show some interesting detail in the form of a thick, softly glowing ring. Although no part of Jones 1 can be termed bright, the northern and southern edges appear slightly enhanced. To best see this dim planetary, wait for a dark, clear night and take advantage of the excellent sky conditions near the zenith.

We wrap up this month's tour back in the Great Square with the barred spiral **NGC 7741**. Through a medium-aperture scope, this galaxy at first appears as a mottled, round haze measuring 2' across. Higher magnifications bring out a uniformly lit bar that extends from east to west across the glow. Apertures of 18 inches or more show hints of the faint surrounding spiral arms. A nice double star consisting of 10th- and 12th-magnitude components separated by 20" lies at the northern edge of the halo and points to the core of the galaxy. ■

Tom Polakis is an aerospace engineer who lives in Tempe, Arizona. His favorite astronomical pursuits are deep-sky observing and photography.

Goin' Steady

Low-tech binocular mounts ease muscle strain and increase viewing pleasure.

by Phil Harrington

There's nothing like sitting back on a clear evening and scanning the sky with binoculars. The only drawback is that holding binoculars for long periods often causes arm strain and an early end to the evening. What you really need is a mount that lets you relax your arms yet steadies your binoculars. Here's a review of low-tech mounts that promise to make your binocular observing sessions more enjoyable.

Four companies offer parallelogram binocular mounts: Blaho Company, T & T Binocular Mounts, Universal Astronomics, and Virgo Astronomics. Prices range from $175 to $300, and the companies offer quick delivery times. I tested each mount using several binoculars of varying powers (7x50mm, 10x50mm, 16x70mm, and 11x80mm) and weighing up to five pounds. Each was evaluated for strength, flexibility, range of motion, and steadiness.

Every binocular mount reviewed also required a sturdy tripod. While several of the following manufacturers offer matching tripods to accompany their binocular mounts, tripods are not included in this review.

William Zuback

Blaho Stedi-Vu

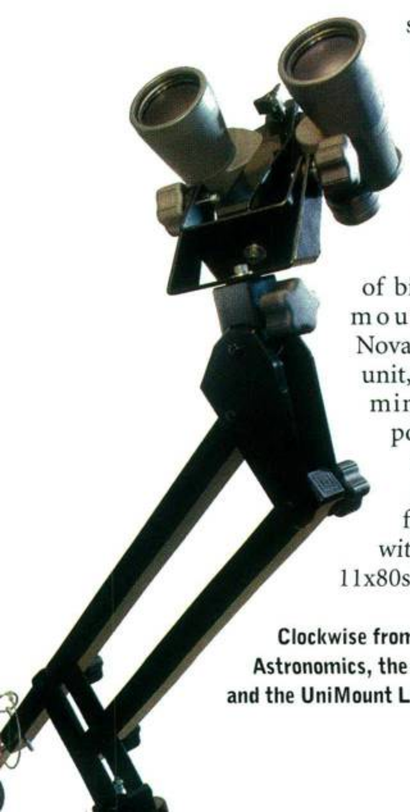
Blaho's Stedi-Vu, designed to support up to 80mm giant binoculars, has a slate-black anodized finish and the nicest appearance of the mounts tested. Constructed of solid aluminum bar stock, the Stedi-Vu was the thinnest, most compact, and sturdiest mount evaluated. The Stedi-Vu features an integrated counterweight for balancing the binoculars. Stedi-Vu's counterweight slides along one of the mount's parallelogram rails and locks in place with two thumb knobs.

Stedi-Vu also comes with a small, built-in "shelf" parallel to and just above the mounting area for the binoculars. This would accommodate a small, 1x finder (sold separately). While not necessary for most binoculars, a finder may come in handy for high-power glasses.

Binocular mounts must allow the user to aim at any point in the sky, and most mounts pivot in several different directions independently. Unfortunately, the Stedi-Vu tilts binoculars only in altitude and relies on the tripod for movement in azimuth. While a minor detail, this underscores the need for a well-made tripod when using a mount.

The only drawback to the Stedi-Vu mount is that the binoculars must line up with the parallelogram, which always places the mount and tripod in front of the user. This makes for uncomfortable viewing while seated, because there's virtually nowhere to put your legs without hitting those of the tripod. Several of the other mounts reviewed allowed the binoculars to pivot to either side of the parallelogram, safer from unintentional bumping of the tripod.

The aptly named Stedi-Vu steadily supported each of my binoculars without a problem and moved smoothly — thanks to stainless-steel bolts and Teflon pads at all six pivot points.



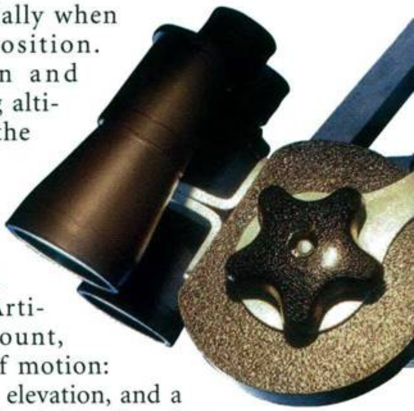
Virgo Astronomics: Sky/mount and Nova/mount

Virgo Astronomics offers a variety of binocular accessories, including two mounts: the Sky/mount and the Nova/mount. Each is essentially the same unit, made from 1" square painted aluminum tubing. Thin, high-density polyethylene (HDPE) bearings separate pivot points. A five-pound counterweight provides balance. I found that these mounts work best with 70mm and lighter binoculars (my 11x80s caused both mounts to wobble).

The less-expensive Sky/mount, also available through Orion Telescope Center, is sold without a mounting bracket. Purchase a bracket separately for $10 to $30 from a variety of sources (including Virgo). The user must attach the bracket into the tapped hole in the aluminum block on the mount with a ¼-inch bolt.

The Sky/mount provides smooth motion in three directions: azimuth (left/right), altitude (up/down), and binocular elevation. A large knob on the altitude axis lets users apply just enough pressure to aim the binoculars without constant readjustments.

The Nova/mount's "cradle-within-a-cradle" fork bracket allows binoculars movement in both altitude and azimuth, independent of the parallelogram mounting itself. This feature greatly enhances the mount's versatility, especially when viewing from a seated position. Observers must loosen and retighten the fork's locking altitude knobs when aiming the binoculars.



T & T ArtiMount

T & T offers eight different binocular mounts. Their most popular, the ArtiMount, or Articulated Mount, swings around four axes of motion: altitude, azimuth, binocular elevation, and a pivoting head. The pivoting head (also found on Virgo's Nova/mount and Universal's UniMount) lets the user swing the binoculars left or right perpendicularly to the mount and tripod, making it easier to enjoy binocular stargazing while sitting down.

The ArtiMount's frame is constructed of 1" square aluminum tubing connected with aluminum side plates. Like the Virgo mounts, T & T uses thin slices of HDPE between each pivot point. Because the ArtiMount is neither painted nor anodized, it has more of a homemade look. Appearances aside, I found the ArtiMount quite capable of supporting all four of my binoculars. Each balanced easily, thanks to the 10-pound counterweight as well as the mount's long counterweight shaft.

I discovered that by adjusting a large side knob, I could aim the ArtiMount at any vertical angle and then release my grip without having to lock the binoculars in place. Another convenient feature allowed me to move the binoculars from point to point using the long, wooden handle that attaches to the mount.

On the downside, the long counterweight shaft works great at balancing heavier binoculars but is too long for smaller glasses. A second mounting hole located about halfway along the shaft would let more of the shaft slip into the mount's bottom tube and better customize the setup.

Universal Astronomics

The most complicated but also most versatile mount I reviewed is the UniMount Light Deluxe by Universal Astronomics. The UniMount is constructed of 1" square aluminum tubing. Teflon spacers held between the beams result in silky smooth motions in all directions, making the UniMount a real swinger. The optional Ultra Swing Mounting System was included with this test model. This feature

Clockwise from bottom left: The Nova/mount from Virgo Astronomics, the Blaho Stedi-Vu, the T & T ArtiMount, and the UniMount Light Deluxe by Universal Astronomics.

FOCUS ON BINOCULAR MOUNTS

BLAHO COMPANY
P.O. Box 419
Pleasant Hill, OH 45359
(937) 676-5891
http://www.blaho.com

Model:
Stedi-Vu
Weight: 13 pounds
Elevation range: 24"
Price: $195

Pros:
- Sturdiest mount tested
- Anodized finish
- Smooth motions
- Integrated counterweight
- Finder mounting shelf

Cons:
- Awkward ergonomics
- No azimuth movement

T & T BINOCULARS MOUNTS, L.L.C.
18 Strong Street Ext.
East Haven, CT 06512
(203) 469-2845
(203) 272-1915
http://www.benjaminsweb.com/TandT/

Model:
ArtiMount
Weight: 15 pounds
Elevation range: 31"
Price: $205

Pros:
- Best buy
- Long counterweight
- Greatest vertical motion
- Four axes of motion
- Smooth altitude and azimuth motions

Cons:
- Homemade appearance
- Stiff azimuth movement
- Long counterweight
- Some play in altitude
- Thin side plates may contribute to torsion

UNIVERSAL ASTRONOMICS
27 Mendon Street
Worcester, MA 01604
(707) 371-0777
http://www.gis.net/~astronut

Model:
UniMount Light Deluxe
Weight: 19 pounds
Elevation range: 33"
Price: $300

Pros:
- Most versatile
- Accommodates binoculars and telescopes up to 12 pounds
- Five axes of motion
- Smooth movements
- Best elevation range
- Counterweight storage
- Video included

Cons:
- Complicated setup
- Heaviest tested
- Optional Ultra Swing Mounting System tends to loosen

VIRGO ASTRONOMICS
608 Falconbridge Rd.,
Suite 46
Joppa, MD 21085
(410) 679-7055

Model:
Sky/mount
Weight: 9.5 pounds
Elevation range: 26"
Price: $175

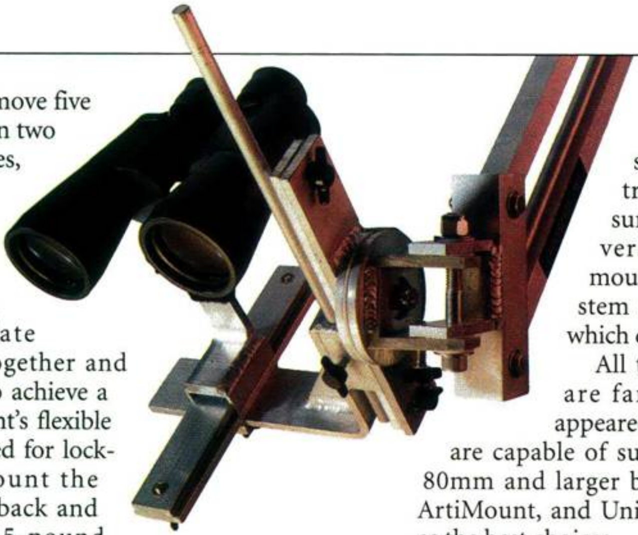
Pros:
- Nice fit/finish
- Smooth motions
- Three axes of motion

Cons:
- 70mm binocular limit
- Mounting bracket not included

Model:
Nova/mount
Weight: 11 pounds
Elevation range: 26"
Price: $300

Pros:
- Nice fit/finish
- Smooth motions
- Four axes of motion

Cons:
- 70mm binocular limit
- Manual altitude lock



allows the binoculars to move five different ways: left/right in two axes, up/down in two axes, and rotating about their central pivot or hinge.

One word describes the UniMount: adaptability. This system consists of several plate assemblies that slide together and adjust in any direction to achieve a perfect balance. UniMount's flexible design eliminates any need for locking knobs. Simply mount the glasses, slide the plates back and forth, and adjust the 15-pound counterweight until balanced. The mount moved smoothly in all directions and every one of my binoculars held their aim when released.

UniMount's telescoping counterweight system is a unique feature. Its adjustable shaft slides into the parallelogram frame, making storage convenient. The counterweight shafts of the other mounts require removal for storage. If you plan to disassemble your UniMount after each use, I strongly recommend purchasing optional storage/carrying bags in order to keep the many pieces together.

The only drawback I found to the UniMount was that its "base stem" (the small aluminum post that screws onto the tripod) tended to loosen itself from the surveyor-style tripod (optional) that Universal Astronomics provided with this mount. A rubber jar-lid gripper between the stem and tripod eliminated the problem — which did not occur with my personal tripod.

All the mounts tested work quite well and are far superior to those that originally appeared on the market about a decade ago. All are capable of supporting up to 70mm binoculars. For 80mm and larger binoculars, the Blaho Stedi-Vu, T & T ArtiMount, and Universal Astronomics' UniMount reigned as the best choices.

Of those three, the UniMount is the most versatile and deserves the rank "best in class." Its innovative design facilitates smooth motions in all directions, with little evidence of wobble or backlash. (I would expect nothing less for the price.) The T & T ArtiMount, however, certainly deserves the label "best buy." For roughly two-thirds the cost, it delivers 80 percent of the UniMount's performance.

Phil Harrington is a frequent contributor to Astronomy.

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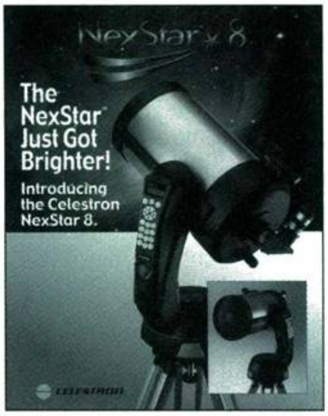
NexStar 8
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Celestron introduces the NexStar 8 inch.

This scope has all the proven features of the NexStar 5, with more than twice the light grasp.

The Go-To Computer system contains 18,000+ objects. The NexStar 8 comes with a/c adapter or runs off 8 AA batteries (not included). All for an amazing $1899 plus shipping.

Other Celestron Telescopes at Lumicon

NexStar 5	$1199
Ultima 2000	$2699
Celestar Deluxe	$1699
Celestar	$1099
CM 1100– 11" SCT	$3199
Starhopper 8" Dob	$429
Starhopper 6" Dob	$339
C102-HD 4" Refractor	$499
FS114 Deluxe	$299
CR150 6" f/8 Refractor (NEW)	$1199

LOSMANDY GM8 & G11 Mounts

The G8 & G11 Mounts are among the finest mounts made in America. Both have dual-axis drive with periodic error correction built in. The GM8 can carry 30 lbs. of equipment, the G11 can carry 60 lbs. of equipment.

GM8 Mount with Tripod	$1499
G11 MountwithTripod	$1899

Other fine Losmandy accessories available.

LUMICON FILTERS - BEST IN THE WORLD BUT WHICH FILTER TO BUY?

LUMICON H-BETA
LUMICON OIII
OIII
LUMICON UHC
LUMICON DEEP-SKY

Lumicon Deep Sky Filters follow the classic broad band curve but offer the highest transmission of nebula lines of any such filter available. Lumicon Deep Sky filters block mercury and sodium vapor lamp emissions while letting thru all other parts of the spectrum. Deep Sky Filters are most useful for astrophotography (color & b&w) and CCD work. Deep Sky Filters are also useful visually, nebula offering the best contrast gain but galaxies, star clusters and dusty comets are also slightly enhanced.

1.25" Deep Sky Filter (fits most 1.25" eyepieces)	$99.50
48mm Deep Sky Filter (fits 2" eyepieces and Lumicon accessories)	$199.50
Visual Back Deep Sky Filter (fits in series on back threads of SCT'S)	$199.50
2" Deep Sky Filter (fits 2" eyepieces and T-threaded accessories)	$199.50
72mm Deep Sky Filter (for the front of large telephoto lenses*)	$399.50

*step rings for other sizes available.

Lumicon Ultra High Contrast Filters have a narrow band pass that lets thru the two oxygen III and the hydrogen beta lines while blocking the remaining visual spectrum. The resulting filter yields high contrast views of all types of nebula. It is best used visually with any telescope of f/6 or longer focal ratio. The Ultra High Contrast Filter is not for photography.

1.25" Ultra High Contrast Filter (fits most 1.25" eyepieces)	$99.50
48mm Ultra High Contrast Filter (fits 2" eyepieces and Lumicon accessories)	$199.50
Visual Back Ultra High Contrast Filter (fits in series on back threads of SCT'S)	$199.50

Lumicon Oxygen III filters isolate just the two oxygen III lines of the spectrum and block the remaining visual spectrum. The Oxygen III filter yields the maximum contrast gain possible on planetary nebula and most emission nebula. Views of the Veil Nebula and others with this filter are beyond words. The Lumicon Oxygen III Filter is for visual use only and is best suited for 6" and larger aperture telescopes with focal ratio of f/10 or faster.

1.25" Oxygen III Filter (fits most 1.25" eyepieces)	$99.50
48mm Oxygen III Filter (fits 2" eyepieces and Lumicon accessories)	$199.50
Visual Back Oxygen III Filter (fits in series on back threads of SCT'S)	$199.50

Lumicon Hydrogen Beta Filters isolate just the hydrogen beta line of the spectrum and block the remaining visual spectrum. The Hydrogen Beta filter was created with a select number of low energy nebula in mind such as the Horsehead, Cocoon & the California nebula. In many instances the Hydrogen Beta filter is the **ONLY** way to see these nebula. The Hydrogen Beta Filter is a visual filter only, best suited to 8" or larger aperture telescopes with focal ratios of f/5 or faster.

1.25" Hydrogen Beta Filter (fits most 1.25" eyepieces)	$99.50
48mm Hydrogen Beta Filter (fits 2" eyepieces and Lumicon accessories)	$199.50
Visual Back Hydrogen Beta Filter (fits in series on back threads of SCT'S)	$199.50

Special Pricing – Buy two or more Lumicon filters and get a DISCOUNT.

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- Motor drive NOT REQUIRED!
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Pronto 70mmf6.8 w/45° erecting prism	$925
Tele Vue 85,85mm f/7 APO telescope	$1995
Bino Vue binocular w/2x correc.	$1030
Gibraltar mount with ash wood tripod	$530
8,11,15mm Plossl . $82 — **20,25mm**	$95
32mm Plossl, widest true field in 1 1/4"	$110
55mm Plossl, widest possible field	$230
2.0x or 3.0x Tele Vue Barlow Lens	$105
2" Giant Barlow – 2x	$168
4.8mm Nagler 82° field, 1 1/4" eyepiece	$175
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12mm Nagler Type 4, 82° 1 1/4 "or 2"	$340
16mm Nagler Type II, 82° 1 1/4 "or 2"	$310
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31mm Nagler Type 5, 82° 2" only	$595
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3,4,6,8,10,14mm Radian,60° field	$228
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19mm Panoptic 1 1/4", 68° field	$240
22mm Panoptic 1 1/4"/2", 68° field	$280
27mm Panoptic 2", 68° field	$330
35mm Panoptic 2", 68° field	$365
NEW! Tele Vue 18mm radian, 60° field	$228.

Note: Tele Vue warranty may not be valid outside USA

Tele Vue's Newest!

Lumicon, always in the forefront bringing you the latest scopes and specials, brings you the newest scope from Tele Vue. The Tele Vue 102 (shown with optional Gibralter Mount) brings you the best of apochromatic optics in a longer 880mm f/8.6 length making it and even better choice for planetary viewing than previous releases.

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Tele Vue tube holder for 102	$120
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Lumicon 2"/1.25" Reducer	$25

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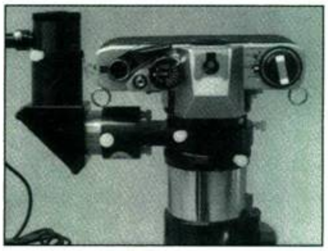
Meade Instruments has dramatically lowered the price of their legendary 8", 10" & 12" LX200 Schmidt-Cassegrain Telescopes. The LX200 telescopes were the first true high speed go to telescope on the market nine years ago — updating and innovations have kept it at the leading edge. LX200 telescopes are more massive than other computer controlled telescopes so they can carry a heavier payload of cameras and exotic eyepieces. The LX200's are built to work in harmony with Meade CCD and guiding equipment but versatile enough to work with other manufacturers systems. Don't let this buying opportunity pass you by.

8"LX200 SCT with Tripod ($105p/s)	$2295
10"LX200 SCT with Tripod ($145p/s)	$2695
12"LX200 SCT with Tripod ($215p/s)	$3995
Wedge for 8" LX200(for photography) ($15p/s)	$139
Superwedge for 10"/12"LX200($35p/s)	$395

3 Choices of our Lumicon Easy Guiders ™



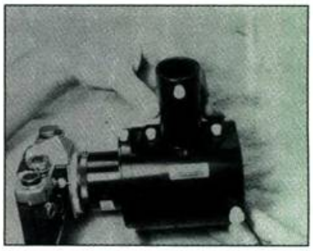
Newtonian Easy-Guider ™

The **LUMICON NEWTONIAN EASY-GUIDER ™** is the best choice on the market for guiding both Newtonian and Refractor telescopes. Off-axis guiding is the surest way to get pin-point star images. The two-way adjustment on the off-axis tube avoids the problems of finding and centering a guide star in your eyepiece or autoguider. A 35mm camera adapter is included (specify camera). Available for either 1.25" or 2" focusers at ....**$189.50 each**

Cassegrain Easy Guider™

For 8" Schmidtt-Cassegrain telescopes choose the **LUMICON CASSEGRAIN EASY GUIDER™.** Includes mutiple adjustments for easily finding and centering a guide star and for composing the picture. The included internal 50mm focal reducing lens delivers brighter f/6 photographic images and can be used visually with an optional adapter. The lens can be removed for f/10 photography. A 35mm camera adapter (specify camera) is included....**$249**

Visual Adapter **$25**



Lumicon Giant Easy Guider™

The king of off axis guiders is the **LUMICON GIANT EASY GUIDER™.** Made for Schmidtt-Cassegrain telescopes of 10" through 16" diameter, the giant easy guider attaches to the large 3" rear threads of these scopes. Included is an 80mm diameter focal reducing lens capable of delivering f/7 to f/4 photographic speed. Replacing the included 35mm camera adapter (specify camera) with a 2" star diagonal turns the giant easy guider into a full aperture rich-field viewer.......................................**$395**

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DS90 EC w/dual drives ($50 p/s)	$499
DS114EC w/dual drives ($45 p/s)	$399
DS127ED w/dual drives ($50 p/s)	$499

Meade Starfinders 6 -16"

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10"f/4.5 Equatorial Starfinder ($99 P&S)	$699
12.5"f/4.8 Dobsonian Starfinder ($95 P&S)	$795
16"f/4.5 Dobsonian Starfinder (frt. COD)	$1195
16"f/4.5 Equatorial Starfinder (frt. COD)	$2695

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated packing and shipping charge to the price. Slightly lower P&S for payment by check. Lumicon showroom prices are $50 to $100 higher.

See the Meade ad in this magazine for full descriptions. Starfinders are complete telescope systems with motor drive and finderscope (Equatorial only) and 25mm (48x) eyepiece. New DC motor runs on four AA batteries.

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NexStar™ 8

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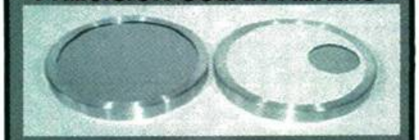

Recognized around the world for product quality and cutting edge advances, our filters are the preferred choice of telescope retailers and used exclusively by NASA aboard the Space Shuttle. Other professional users include: ABC, BBC,CBS, NBC, CNN, NOVA, The Discovery Channel, National Geographic and most major universities and observatories. Tens of thousands are in use world wide.

TYPE 2+ - Made with high quality hand select glass and coated with our exclusive Solar II Plus. The most durable filter on the market. Transmission is 1/1,000th of 1%. (OD-5). Great for both visual and photographic use. Solar Image is yellow-orange. Guaranteed 15 yrs.

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APERTURE	Full Aper.	Off-Axis	Full Aper.	Off-Axis
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3.5" to 4"	79.00	N/A	59.00	N/A
4.25" to 5"	99.00	N/A	69.00	N/A
6"	109.00	$ 79.00	$ 79.00	$ 69.00
7" to 8"	129.00	89.00	89.00	79.00
10"	149.00	109.00	N/A	89.00
11"	159.00	119.00	N/A	99.00
12" to 13.1"	179.00	139.00	N/A	119.00
14"	199.00	149.00	N/A	139.00
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ETX-125/EC $895.
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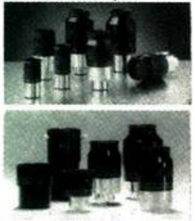

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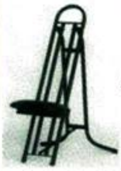

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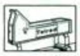

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Mention Ad A-7

ask Astro

Stellar Lifetimes, Gravity, Dobsonian Telescopes

If all these stars and galaxies are millions of light-years from us and we are only now seeing what existed millions of years ago, how do we know they are still there? — *Jim McGillan, McLean, Virginia*

Let's pretend that I'm looking out my office window at the company parking lot. I see my friend and *Astronomy* colleague Rich Talcott about 100 yards away walking toward the building's main entrance. How do I know that Rich is still alive? After all, it takes a certain amount of time for the light reflecting off Rich's body to reach my eyeballs.

I can be very (but not 100 percent) confident that Rich is alive because the time it takes the light to travel between Rich and me is incredibly short (0.0000003 second) compared to the typical lifetime of a human being. So even though there's a chance Rich will die (I hope not!) between the time the light reflects off his body until it reaches me, that probability is so incredibly small that I don't need to worry about it.

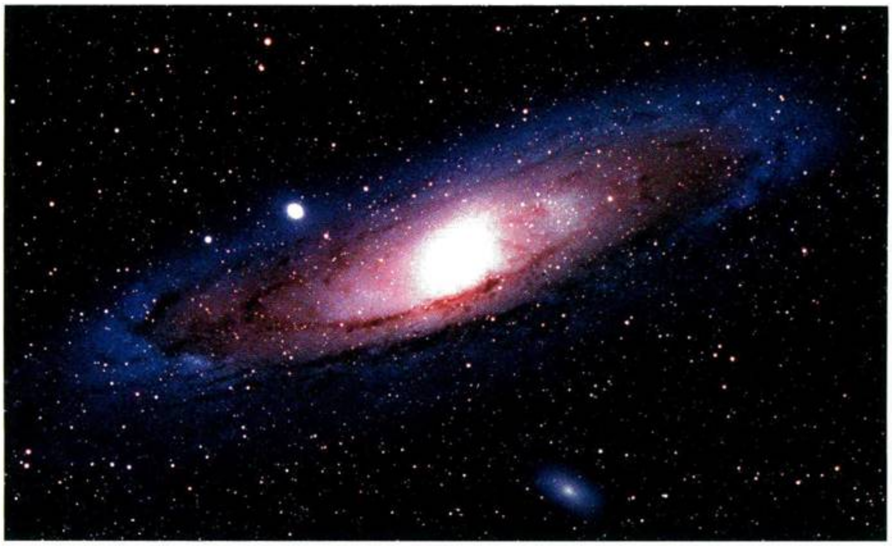
In the same way, the lifetime of stars in our galaxy is very long compared to the time it takes their light to reach Earth. The closest stars are a few dozen light-years from Earth, while stars on the other side of the galaxy lie tens of thousands of light-years away. But stars live for millions, billions, or even trillions of years. Because stars live so long and evolve so slowly, most of them in our galaxy are still around, and in more or less the same state, even though we see them as they existed in the past.

As for galaxies, the relatively nearby Andromeda Galaxy (M31) is only 2.4

Above: Galaxies in the Hubble Deep Field would look very different today. HDF Team/STScI

Below: Just about all the stars in this Milky Way starfield still exist. Michael Stecker million light-years away. If we could look at it as it exists today, it would appear similar (but not identical) to the way it appears in our telescopes because stars and galaxies don't evolve very much in 2.4 million years.

But the situation is very different when astronomers look at galaxies billions of light-years away. Light travels fast, but not infinitely fast. This means that astronomers can use telescopes as time machines to probe what conditions were like when the universe was much younger. The famous Hubble Deep Field, for example, shows galaxies as they existed more than 10 billion years ago. That's so long ago that the galaxies have evolved significantly since then. In fact, many Deep Field galaxies appear small and undefined compared to their nearby counterparts. If we could see these Deep Field galaxies as they exist today, they would undoubtedly look a lot different, and some of their stars would no longer exist. — *Robert Naeye, senior editor*



The Andromeda Galaxy (M31) would look virtually the same if we could see it as it exists right now, rather than as it existed 2.4 million years ago. Jerry Lodriguss

I understand Albert Einstein discovered that gravity is not a force but actually a warping of spacetime caused by the presence of mass. But gravity is also defined as one of the four fundamental forces. Which of these views is correct? — *Mark Mumaugh, Cheyenne, Wyoming*

Let me answer this good question in two ways. First, gravity *is* one of the four fundamental forces of nature, with the other three being the strong nuclear, weak nuclear, and electromagnetic forces. What Einstein realized is that the mechanism by which gravity exerts its influence involves warps and ripples in the fabric of spacetime. Just as a bowling ball sitting in the middle of a large rubber sheet will cause the sheet to warp, thereby affecting the motion of other bodies (such as marbles) rolling around on the sheet, an object such as the sun causes the fabric of spacetime to warp, thereby affecting the motion of other bodies (such as planets) "rolling around" on the spacetime fabric. In this way, gravity is a force whose influence is communicated by warps in spacetime.

Although you can take this as a complete answer, let me raise another subtle feature. One of the crucial thoughts that led Einstein to his picture of gravity (his general theory of relativity) is that if you were to, say, fall out of a window, during your descent you would feel weightless. Without a floor pushing up on your feet, you would not have the usual sensation of "weightfullness." More directly, if you and your scale fell out of the window together, you would both fall at the same rate and hence your feet would exert no force on the scale, leaving its reading at zero. So, when you are in free fall you do not experience the force of gravity in the usual way.

Instead, gravity's role is in warping the spacetime fabric, thereby affecting (in fact, determining) which paths constitute free fall motion. In a sense, then, from a freely falling perspective, there is no feeling of gravity, and all that matters is the curvature of spacetime. This is why people sometimes say that gravity is not a force, that it is only the curvature of spacetime. But as I wrote above, I think it best to consider gravity as being both a force and a warping in spacetime. — *Brian Greene, Columbia University, author of* The Elegant Universe

Can I put a motor-drive on a Dobsonian telescope for astrophotography purposes? — *Tomas Garcia, Boynton Beach, Florida*

Yes, but it is very difficult. Dobsonians are altazimuth mounted telescopes. This means the axes of rotation are not aligned with Earth's rotation (except at the poles).

The trick is to drive the altitude and azimuth bearings at the proper speeds no matter where the scope is pointing. This means using separate drive motors for both the altitude and azimuth bearings. A small computer similar to those used with digital setting circles tells each motor how fast to turn to compensate for Earth's rotation. Devices called shaft encoders tell the computer how far the scope is moving in both axes so it can signal the drive motors.

Field rotation is another big problem to overcome. As the telescope tracks the sky during a long exposure, the orientation of the image rotates. This doesn't happen in equatorially mounted telescopes. Dob users must find a way to rotate the camera exactly to follow the rotation of the field during the exposure. It's not a problem for exposures less than a couple of minutes. But for longer exposures, the stars will smear into arcs unless the problem is solved.

Professional telescopes such as the Kecks in Hawaii use altazimuth mounts and sophisticated computers to rotate at just the right rate. But it's simply not practical to put a complicated drive system on a Dobsonian for astrophotography. The solution for amateurs comes with an equatorial platform. Set your Dobsonian on top of such a platform and it will track as an equatorial telescope. — *Dave Kriege, Obsession Telescopes®, www.obsessiontelescopes.com*

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strange Universe

by Bob Berman

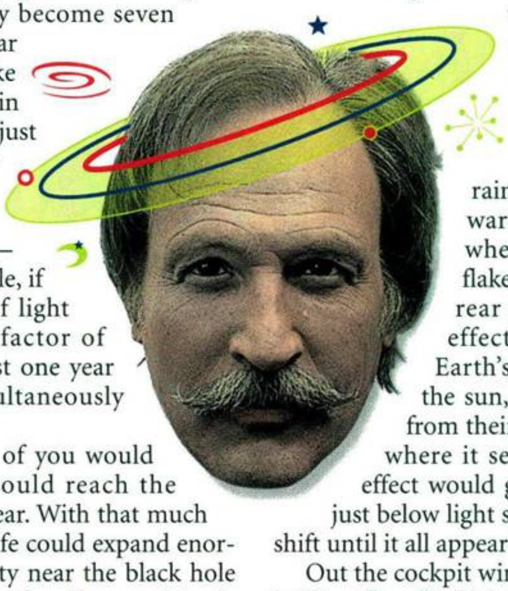
Light Speed Follies

At high speeds or in places with very strong gravity, funny things happen on the way to work. Time slows down — not good if you already have a boring job — and distance shrinks as well. Time dilation has been amply exploited by science fiction writers, but the warping of distance has drawn much less attention.

It means that if you could travel at 99 percent of the speed of light, the universe would suddenly become seven times smaller than it was before. A star seven light-years distant from us (like Sirius, which is now becoming visible in the predawn sky) would magically float just a single light-year away — reachable by your next birthday.

The effect becomes amazing as you zoom to just under the speed of light — 186,282.4 miles per second. For example, if you traveled 99.999999999 percent of light speed you'd experience a dilation factor of 22,361. Your clocks would tick off just one year while more than 223 centuries simultaneously elapsed back on planet Earth.

In addition, all distances in front of you would shrink by this same margin. You could reach the nucleus of the Milky Way in a single year. With that much territory at your disposal, your social life could expand enormously. You could hold your next party near the black hole at the galaxy's center and toss in pretzels, olives, and tonic water just for laughs.



Of course, there's no escaping the fact that when you returned, the party would really be over. During your two-year round-trip, 45 thousand years would have passed on Earth. New social mores and technological advances would have made our world unrecognizable. You'd be seriously old-fashioned, and we're not talking about whether bell-bottoms would be "in" or "out." You'd be lucky if they didn't throw you into a zoo.

The 25,000 light-year round-trip toward Sagittarius would actually require more than two years. Sci-fi odysseys often ignore the issue of comfort. The journey would be more enjoyable if you made the acceleration and deceleration gradual enough for you to survive the g forces. Too much of a "Let's go!" attitude is a bad thing when an antimatter engine is under the hood. Push the throttle too hard, zoom to within a percentage of light speed in anything less than a week, and you'd be instantly converted into a smooth film of protoplasm on the back wall. To use real numbers, stretching out the acceleration for a full year would safely bring you to the desired speed with a steady one-g pressure.

Forget about sight-seeing along the way. Another wrinkle is that near the speed of light, everything in the universe would seem to lie directly ahead. This happens because of what scientists call aberration.

When walking briskly through a rain shower, we must tilt the umbrella forward a bit to keep from getting wet. Or when driving through a snowstorm, the flakes seem to come from ahead while the rear window hardly gets hit at all. This effect is also seen with light. Because of Earth's 18 mile-per-second motion around the sun, stars are displaced several arcseconds from their true positions — meaning, nothing is where it seems to be! If we traveled faster this effect would grow increasingly pronounced until at just below light speed, everything in the universe would shift until it all appeared dead ahead.

Out the cockpit window would hover a solitary, blindingly brilliant "star," which is everything in the universe clumped into one dazzling ball. It would be surrounded by blackness. And from the rear window our fearless astronaut sees — absolutely nothing.

Light uses a variety of methods to tease us with its outrageousness. The famous number 186,282 represents its speed in a vacuum, but light moves more slowly in denser media such as water. Well, consider this: When light hits a window, it abruptly slows while traveling through the glass. But then it instantaneously speeds up again when it reaches the other side. Whaa? (Material objects slow down when meeting obstacles, but they do not then spontaneously resume their previous speed!)

It's too bad we can never reach the speed of light to experience totally frozen time and zero length. If you could trade places with a photon — walk a mile in its shoes — so to speak, you'd experience yourself as everywhere in the universe at once!

Then there's the redshift and blueshift thing. While each photon of light amazingly hits you at precisely the same speed regardless of whether you're crashing into it head-on or racing away from its source, your travel does cause it to change color. In demonstrating spectroscopy to students and looking at the three colorful emission lines given off by the glowing mercury vapor in streetlights, I've often wished my students could take turns running toward the lamp while looking through the instrument. It would be fun to see the yellow line turn green, the green one turn blue, and the violet line vanish as it shifts into the ultraviolet. Alas, our class members may be too sluggish to move fast enough to see this "blueshift" for themselves.

But our high-velocity future astronaut will indeed watch the universe change tint. Sealed within a bewildering but psychedelic cocoon, he'd appear the same as before when looking at a mirror, but neither the position, appearance, time, length, nor color of the universe would match the view of those back home.

It's strange, all right. But it would let future travelers go anywhere in the cosmos while hardly aging; all this without violating any rules of physics. So it's not necessary to reach Warp Seven, nor exceed light speed, nor do any of the no-nos prohibited by science. We can obey the law and still get there, even to other galaxies.

The only wrinkle with truly distant high-speed travel: Earth is aeons older when you return. Your descendants have evolved: They're no longer human. Your jokes don't get a laugh. You want to tell everyone about your travels to Andromeda, but your words sound like monkey grunts to them. The new earthlings eventually just shrug and eat you.

This is a bad day by current standards. Still, to witness aeons of Earth's history, wouldn't you buy a ticket?

Bob Berman's Strange Universe is now a montly feature in Astronomy *magazine. Berman is the author of several books, including* Secrets of the Night Sky: The Most Amazing Things in the Universe You Can See with the Naked Eye *and* Cosmic Adventure: A Renegade Astronomer's Guide to Our World and Beyond.

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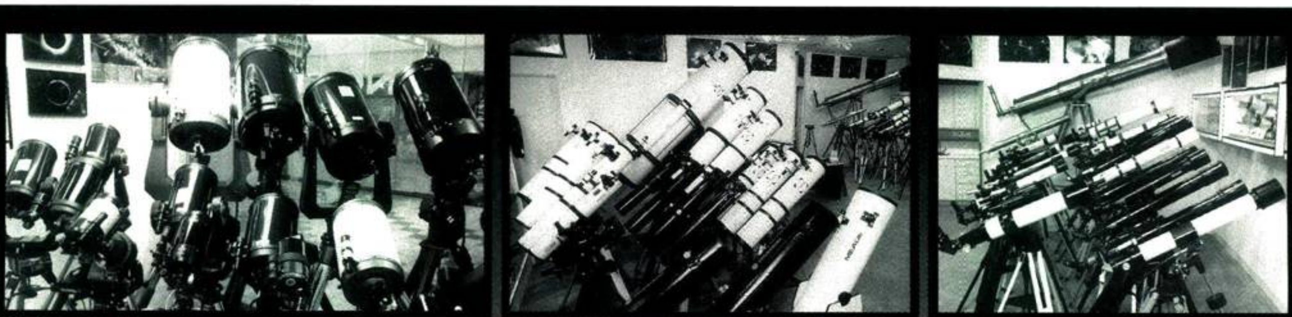

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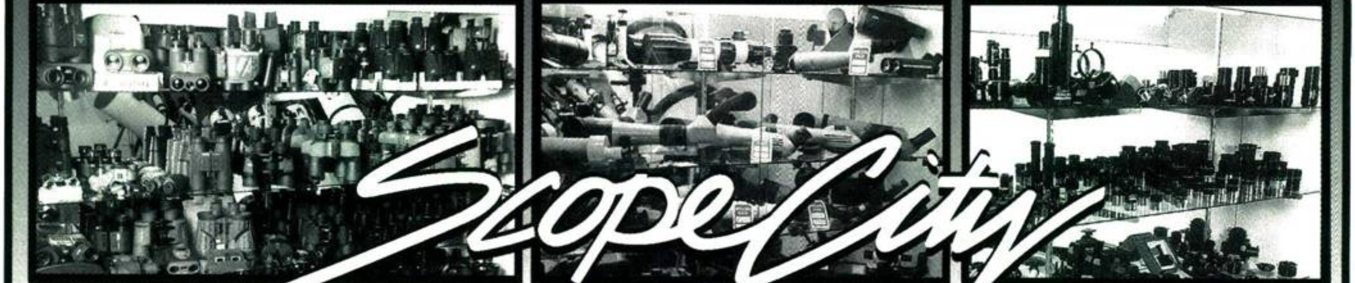

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PRODUCTS

Prism Binoculars

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▶ Nikon has introduced the E2 binocular, an upgrade of its classic Porro prism binocular, in 8x30mm and 10x35mm configurations. The E2 has a restyled, ergonomic, magnesium-alloy chassis with a rubber shell that provides a sure grip and added durability. The 8x30mm E2 is only 4 inches by 7.1 inches and weighs 20.3 ounces. The 10x35mm is slightly larger and lighter.

The E2 series use high-index BaK4 prisms as well as Nikon's Eco Glass, which is manufactured without the use of lead or arsenic. The binoculars also have antireflective multicoatings on both lenses and prisms to provide true color rendition, high light transmission, and flare-free viewing.

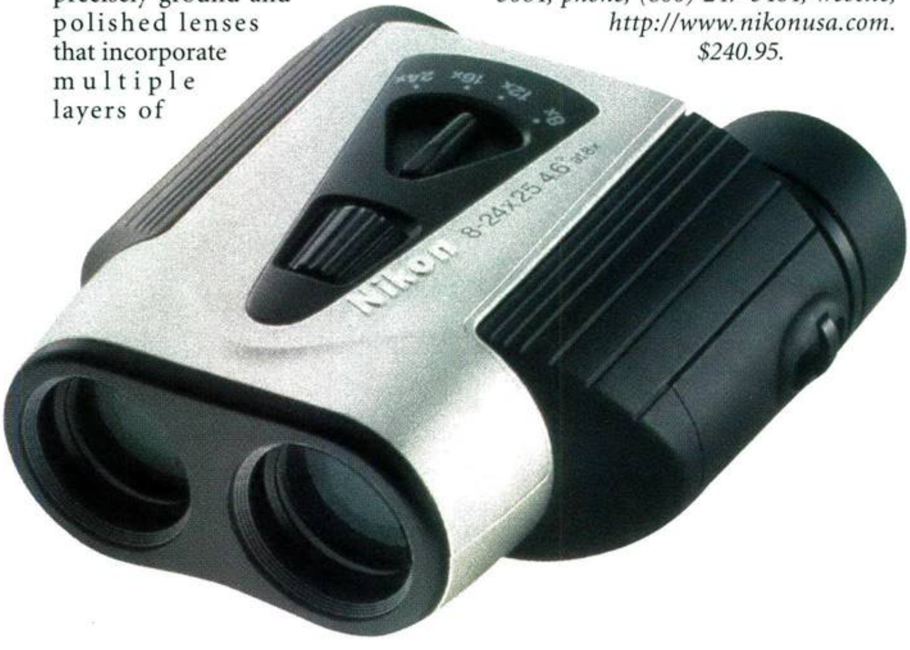
The 8x30mm has a 461 foot field of view at 1,000 yards. The 10x35mm has a 366-foot field of view at 1,000 yards. Both have a 70° apparent angle of view, qualifying them as wide-angle binoculars.

Nikon Sport Optics, 1300 Walt Whitman Road, Melville, NY 11747-3064; phone, (800) 247-3464; website, http://www.nikonusa.com. 8x30mm: *$730.95,* 10x35mm: *$800.95.*

Zoom Binoculars

▶ Nikon also has introduced the 8-24x25mm Eagleview Zoom II, an optically updated version of a popular binocular. The latest model is built on a dual-hinge polycarbonate body with a tough, comfortable elastomer coating. Measuring a mere 4.3 inches by 4.7 inches and weighing only 12.5 ounces, the Zoom II has precisely ground and polished lenses that incorporate multiple layers of Nikon's antireflective coatings, allowing high light transmission, true color rendition, and crisp, clear images. The Zoom II has a central focus, a 4.6° field of view at 8x, and its turn-slide rubber eyecups allow the eye relief needed for optimum viewing, with or without glasses.

Nikon Sport Optics, 1300 Walt Whitman Road, Melville, NY 11747-3064; phone, (800) 247-3464; website, http://www.nikonusa.com. $240.95.



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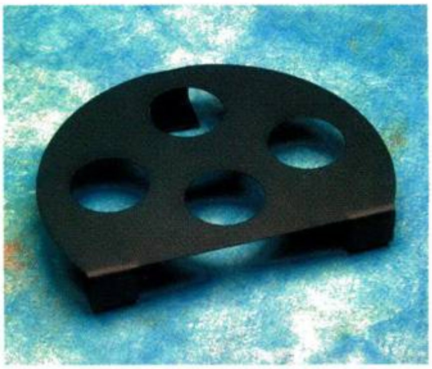
▶ Users of the highly portable NexStar5, a 5-inch Schmidt-Cassegrain telescope made by Celestron, now have a handy place to put their extra eyepieces — the NEXTRAY eyepiece holder. This 4-ounce metal-alloy tray holds four eyepieces and is designed for easy set up and removal. The NEXTRAY device attaches to the NexStar5's battery-compartment cover with three Velcro feet and can be attached or removed in seconds.



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universe 2001
Rose Center for Earth and Space
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2001, a Space Calendar

▶ Of course the millennium actually begins in January, and what better way to commemorate it than with an astronomical calendar? From Jupiter's fiery moon Io to ultraviolet radiation released by the sun's hot corona, a wall calendar published by Hudson Park Press for the Rose Center for Earth and Space at the Hayden Planetarium in New York offers a tour of the universe in 12 lovely months.

The astronomical objects were shot by the Solar and Heliospheric Observatory, the Galileo Spacecraft, the Hubble Space Telescope and other observatories, and the images include whirling galaxies, colorful nebulae, and jovian moons.

Publishers Group West, 1700 Fourth Street, Berkeley, CA 94710; phone, (800) 788-3123; $11.95 ($18.50 Canada).

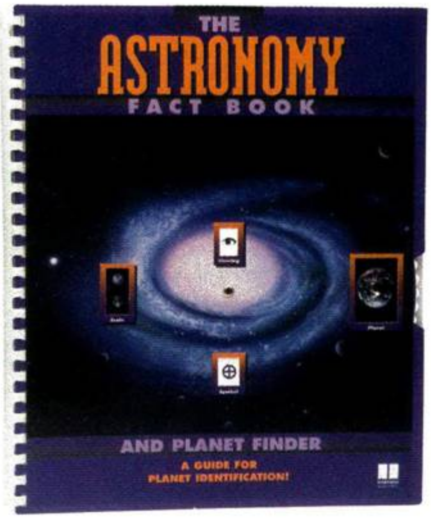
BOOKS

The Astronomy Fact Book and Planet Finder

Richard Whittingham, 38 pages, Hubbard Scientific, Chippewa Falls, WI, 1999; ISBN 0-8331-6700-6; hardcover, $19.95.

▶ *The Astronomy Fact Book and Planet Finder* would be a valuable addition to the library of any school or astronomically inclined family. The 38 large-format, spiral-bound pages have beautiful, nicely displayed images, easy-to-understand illustrations, and clearly explained concepts.

The 10 "chapters" are only a few pages in length and include well-chosen lists. For example, the chapter on stars has a catalog of the brightest stars, the nearest stars, and examples of the major spectral classes of stars.



The 88 constellations appear in alphabetical order and are sketched in star charts for the Northern and Southern Hemispheres. *The Astronomy Fact Book and Planet Finder* will only whet the appetite for the most curious readers, who will soon want to read more and more. The book has short, authoritative, and compelling summaries of the universe — from the sun-Earth-moon system to stellar evolution — that prompt the beginning astronomer to pursue his or her interests. Richard Cox, director of the Hansen Planetarium in Salt Lake City, Utah, updated the book, which was originally written by Richard Whittingham.

Quintessence: The Mystery of Missing Mass in the Universe

Lawrence Krauss, 356 pages, Basic Books, New York, 2000; ISBN 0-465-03740-2; hardcover, $26.

▶ Depending on your point of view, it's either exhilarating or depressing that scientists don't know what makes up 95 percent of the cosmos. Physicists have not yet identified this "dark matter," although they may be closing in on several key suspects. Even stranger, a "dark energy" appears to permeate space itself, making the universe expand at an ever-quickening pace.

These unsettling notions are familiar to those who follow current events in astronomy. However, each new hypothesis about exotic, ghostly particles or vacuum energy seems to stretch believability to a breaking point and astrophysics starts sounding less like science and more like science fiction.

Those who harbor such warranted skepticism would do well to read *Quintessence*, in which physicist Lawrence Krauss makes the case for dark matter and dark energy in great depth and with considerable flair.

Quintessence is a revised edition of Krauss's popular 1989 book *The Fifth Essence*. So much has happened in physics and astronomy during the intervening decade that the revision is extensive indeed, and it serves as a welcome update.

Krauss knows of what he speaks; he is chairman of the physics department at Case Western Reserve University in Cleveland, Ohio, and a noted particle-physics theorist and cosmologist. He's also an adept writer, as shown by his best-selling 1996 book, *The Physics of Star Trek*.

Krauss's expertise is both a blessing and a curse in *Quintessence*. He offers a thorough history of how astrophysicists became convinced that dark matter is out there. The observational evidence — such as the faster-than-expected rotations of spiral galaxies — is clearly presented and easy to grasp. But the underlying theories of physics and cosmology may tax readers who haven't taken courses in those fields.

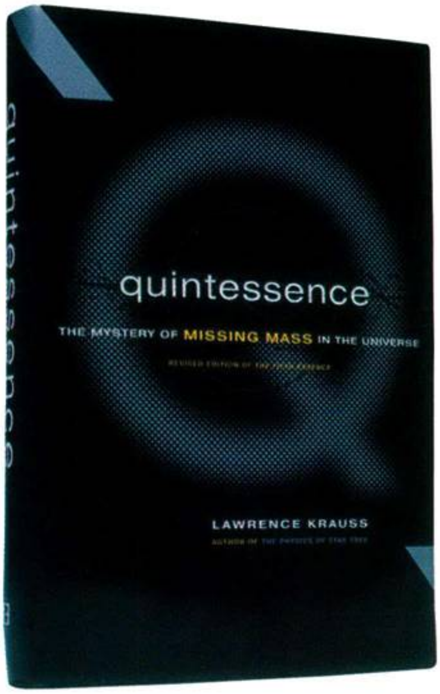
Krauss goes into exhaustive detail on the inflation scenario of the early universe, how the elements arose, and why a hypothesized relationship among particles called "supersymmetry" might lead to certain types of dark matter known as weakly interacting massive particles (WIMPs). It's heavy going, and Krauss acknowledges that. Most of the illustrations are dry schematic drawings and graphs, contributing to the academic impact of parts of the book.

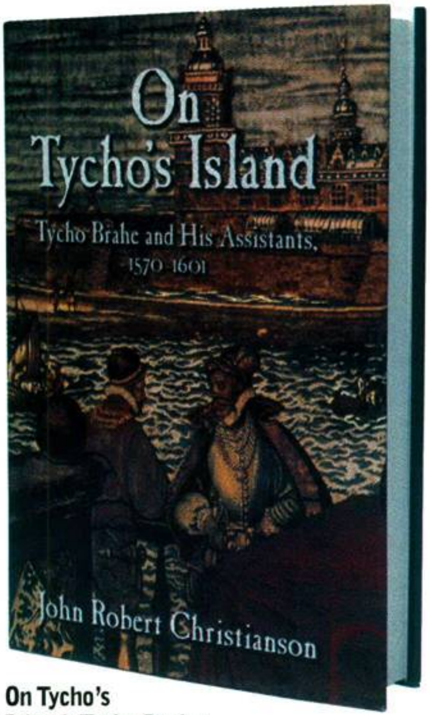
Krauss is at his best toward the end, when he describes the ongoing searches for various forms of dark matter. We learn that within our solar system, a volume of space the size of Earth contains about a pound of dark matter at any given time. Krauss also explains that dark-matter particles interacting with a detector on Earth may produce a signal with one-trillionth as much power as the radioactivity emitted naturally by your big toe.

The experiments with which physicists are trying to detect axions, WIMPs, MACHOs, magnetic monopoles, and other theorized forms of dark matter are fascinating, and Krauss tells a compelling detective story about the hunt.

The narrative also hits its stride when Krauss discusses why the quest for dark matter and dark energy are central to science today. "As long as the identity of the most dominant form of matter in the universe today remains unknown to us, we cannot claim that our scientific picture of the world even approaches completion," he writes. In that respect we are not unlike the ancient Greeks, Krauss observes, with the exception that our concepts of the universe are drawn from experiments rather than philosophical musings.

At the conclusion of *Quintessence*, Krauss wonders whether our ideas about dark matter today will seem as quaint 2,000 years from now as those of ancient Greeks seem to us. He thinks not. The strength of this thought-provoking book is that scientists and nonscientists alike should learn enough to debate that point far into the night. — *Robert Irion, contributing editor*





On Tycho's Island: Tycho Brahe and His Assistants, 1570–1601

John Robert Christianson, 452 pages, Cambridge University Press, New York, 2000; ISBN 0-521-65081-X, hardcover, $34.95.

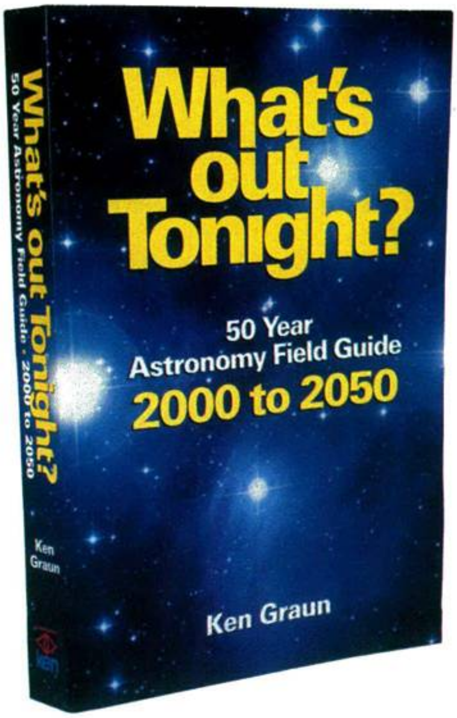
▶ Take a remote island off Denmark, throw in some astronomers, mathematicians, and scientists, add a healthy dose of funding, and you pretty much have an intellectual paradise. The island of Hven, otherwise known as Tycho's Island, was the center of an amazing number of scientific breakthroughs in the late 1500s, thanks to astronomer Tycho Brahe's patronage skills. Although today we'd call it networking, Tycho used similar tactics with King Frederick II to master the art of funding and support in order to establish one of the first scientific research facilities in the world. *On Tycho's Island* is the story of Uraniborg, the utopian community from which many discoveries and innovations arose.

Christianson got the idea for this book by storing names of Tycho's coworkers in a shoebox and years later researching their links to the island. How Tycho managed to secure Hven as his scientific retreat and gather an international, multicultural assembly of academics and artists (among them Johannes Kepler) provides plenty of fodder for the first part of this book. The second half is devoted to biographies of these scientists and intellectuals. For insights on the evolution of modern-day research in astronomy as well as other scientific and artistic venues, spend some time *On Tycho's Island*.

What's Out Tonight? 50 Year Astronomy Field Guide, 2000 to 2050

Ken Graun, 368 pages, Ken Press, Tucson, Arizona, 1999; ISBN 1-928771-00-9; softcover, $39.95.

▶ *What's Out Tonight?* is one of the few astronomical field guides you will need in North America for the next half-century. Amateur astronomer Ken Graun packs his book with basic information such as sunrise and sunset times, meteor showers, moon phases, planetary positions, deep-sky objects, and advice on telescope purchasing. Divided into discreet sections, *What's Out Tonight?* includes tables, maps, charts, and observing tips to help anyone locate and identify objects in space. Photos and diagrams emphasize the text and offer lasting visual impressions. The book's heavy stock and large print also make it ideal for night usage. You can order a copy directly from www.starsafaris.com (or call toll-free 800-870-3616) or order it from other major booksellers.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MEDIA

Warner Brothers Pictures

Space Cowboys

▶ John Glenn's recent return to space inspired the filmmakers of *Space Cowboys*. This summer's high-tech space adventure film was made in cooperation with NASA. The movie depicts the fictional story of an Air Force unit of cocky test pilots who were ready to be the first Americans in space when NASA suddenly decided to use a chimpanzee named Sam instead. The crew, named Team Daedalus, was pushed aside. The team members eventually retire, but the dream of going into space lives on.

A satellite that Frank Corvin (Clint Eastwood) designed fails and threatens to slam into Earth. There is only one man alive — Corvin — who can fix the ailing craft, and he gets to pick the crew he trusts to do the job with him. *Space Cowboys* stars, pictured left to right, are James Garner, Tommy Lee Jones, Eastwood, and Donald Sutherland.

Warner Brothers Pictures, August 4 release: website, http://www.spacecowboys.net.

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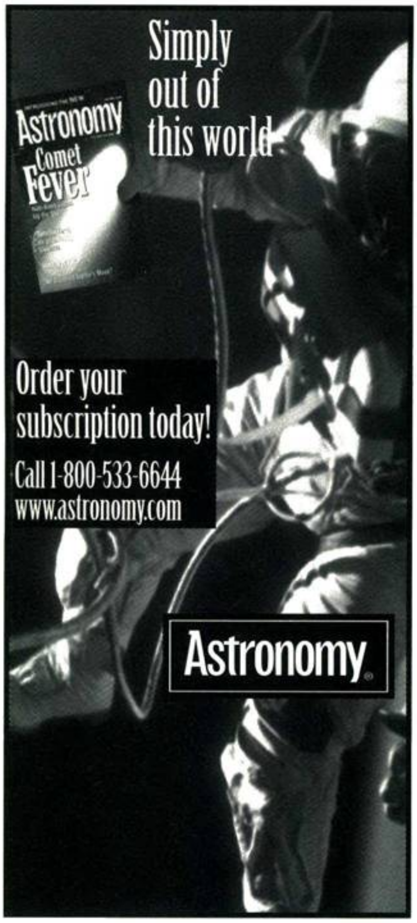

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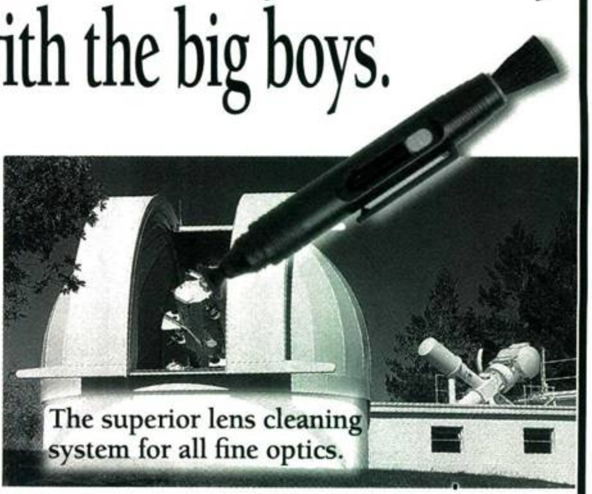

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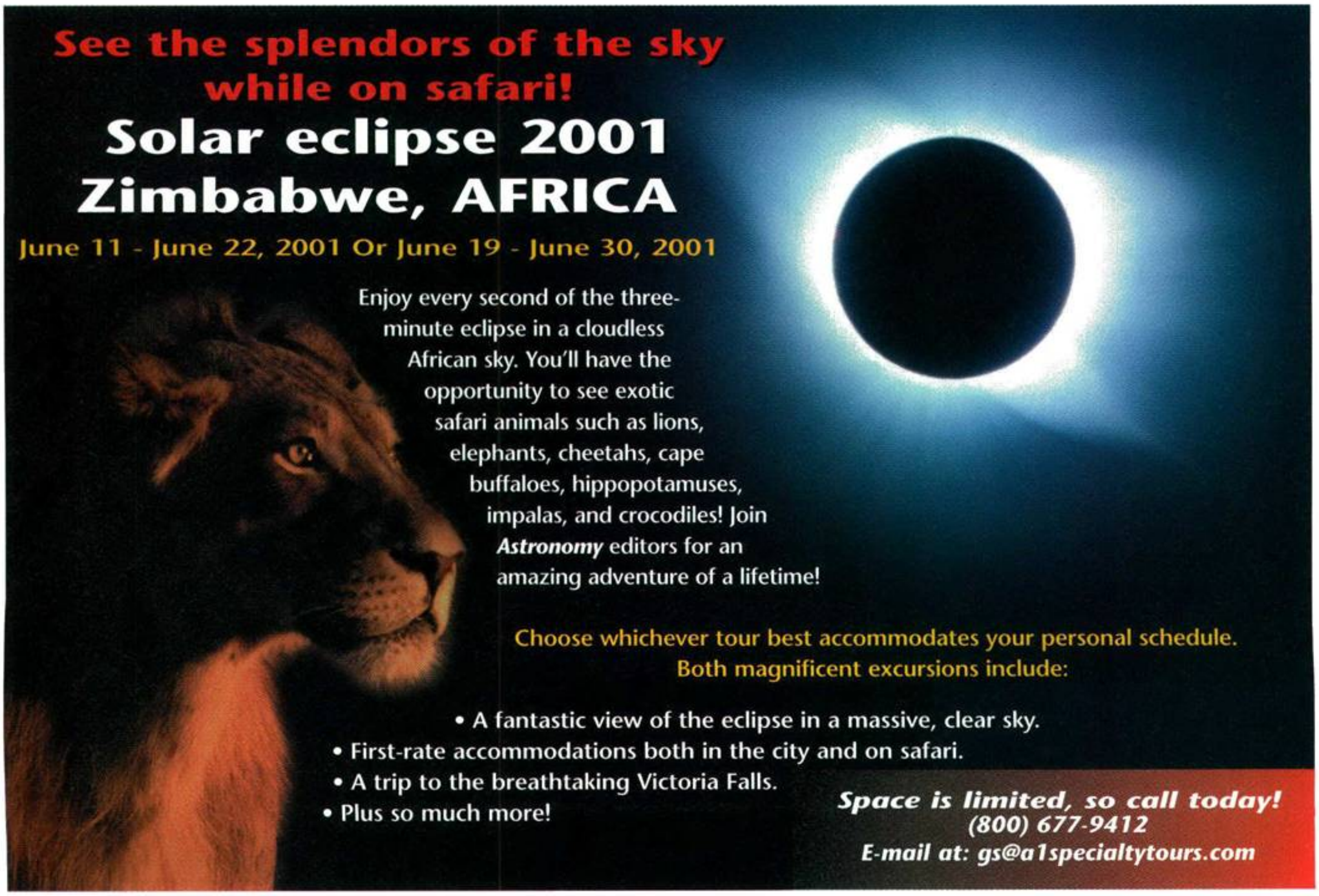

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Meade 7" LX200 **$2795**

Great values at their former prices, Meade LX200 fully computerized go-to scopes are now spectacularly affordable with a price cut of $500 each! It doesn't matter whether the right scope for you is a 7" **LX200 Maksutov**, shown to the right, or an 8" to 12" aperture **LX200 SCT**, Meade has priced each one $500 below what it sold for only a few short months ago.

8" LX200 SCTs are only $2295. Best-selling 10" LX200 SCTs are only $2695, the same price as a competitor's 8" scope. The 12" LX200 SCT is $3995, while the 7" LX200 Maksutov shown above is only $2795. While backorders *are* possible at these low prices, if Meade is shipping a scope for a dealer to keep in stock, chances are good we *have* it in stock.

Meade prices are about the same anywhere you call. So why order a Meade product from a dealer who charges your credit card, then makes you wait and wait until he finally gets around to ordering what you want? Not when you can usually get the Meade you want . . . right now . . . at the right price . . . right here at ***astronomics.***

We have 128 Meade ETX-125s in stock!

Meade 5" ETX-125EC
$895

At the time this was written (6/1), we had 128 ETX-125EC 5" Maksutov-Cassegrains in stock, with 400 more scheduled for delivery before the end of the year.

With more than 200 sold during the first three months of this year alone, the ETX-125EC is one of our best-selling scopes.

And we don't just have ETX scopes. We have Autostar computers, cases, tripods, eyepieces, electric focusers, filters, camera adapters, and more. If it's a Meade accessory for the ETX-125EC – or any Meade telescope – chances are good we have it in stock.

Special Celestron 8" Dob package price!

Celestron 8" Dob package
$???

We've improved more than 50 of the 8" Celestron Dobsonian reflectors we have in stock by adding a Telrad finder, a 10mm SMA eyepiece (it already comes with a 25mm), and a 2x Barlow. Then we priced the entire package at . . . sorry, but you'll have to call us at (800) 422-7876 to discover our low price – the lowest in the country for a Celestron Dob with all these extras.

3-day air shipping at no extra cost!

We ship by three-day air UPS from our warehouse to our East and West Coast customers at no extra charge above our regular shipping (except for scope cases, Dobsonians, dewshields, and a few other big items). No matter where you live in the 48 continental United States, your order should arrive by the third business day after we ship. UPS can't guarantee 3-day delivery in case of bad weather or during peak seasons, so UPS service guarantees do not apply to this limited time free upgrade if shipments are delayed.

A fully-computerized *8"* go-to scope for only $1899? *Amazing!* And we have 54 in stock!

You read that price right. Only $1899 for a fully-computerized go-to 8" telescope. Even better, the new **Celestron NexStar 8** can be powered by AA flashlight batteries. You're never tied down to an AC power outlet or a heavy rechargeable battery pack to use your scope.

The **NexStar 8** puts sharp, bright f/10 Schmidt-Cassegrain optics into a sleek metal housing that brings go-to scopes into the 21st century in style!

Celestron NexStar 8,
$1899

The NexStar's standard computer hand control stores in a recess in the scope's rigid single metal fork arm (and operates while stored there, as well as when it's undocked and hand-held at the end of its coiled cord). The computer quietly moves the AA battery-powered NexStar at a fast 6.5° per second to 18,473 stars and deep space objects, all the non-stellar objects you can see in an 8" scope. The computer also takes you on guided tours of the most spectacular deep sky objects. Standard equipment includes electric slow motion controls; a NexStar Plössl eyepiece; and a non-magnifying long eye relief Star Pointer red dot finder that's ideal for eyeglass wearers. An AC adapter is standard, not a costly option.

You can experience the heavens only a few days after you order a **NexStar 8** from ***astronomics!*** With 54 in stock on 6/2 and over 300 scheduled for delivery over the next six months, chances are good we have one in stock for you.

Our free catalog helps you pick the right Meade, Celestron, Questar, Takahashi, or TeleVue scope.

For detailed information on individual products, visit our Web site. Or call us at (405) 364-0858, or e-mail us, for your *free* copy of our catalog AST. It covers all the scopes and accessories we stock – from Apogee, Bushnell, Canon, Celestron, JMI, Lumicon, Meade, Pentax, Questar, Rigel Systems, SBIG, Software Bisque, Takahashi, TeleVue, and more. We'll include our 8-page guide on how to pick the right scope and your discount prices on the 1000+ products we carry. (Sorry, U. S. sales only.) The catalog is yours for only the cost of a one minute phone call. The information we send will make it the most useful minute you'll ever invest in astronomy.

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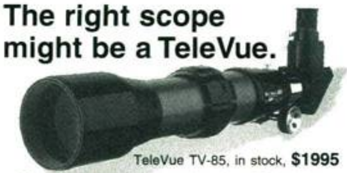
The right scope might be a TeleVue.



TeleVue TV-85, in stock, **$1995**

Hardly a week goes by that TeleVue doesn't send us copies of new warranty cards filled with glowing comments that our customers have written about the new TeleVue scopes they bought from us. But we don't need to be reassured about TeleVue quality. We've come to expect nothing but praise for TeleVue, which is why we stock them in depth. We had 36 people-pleasing TeleVue scopes in stock and 45 more on order at the time this was written (6/2).

Pronto, **Ranger**, **TV-85**, **TV-101**, the new **TV-102** optical tube assembly, the brass **Renaissance** – all are built to the same uncompromisingly high optical and mechanical standards. Their short focal lengths give you an observing flexibility many other scopes lack. Each has the ability to go from very low power wide angle views (as low as 9x in some cases, with a wide 5.7° field) to very high power observing, all without losing optical quality (one test report said they used an amazing 89x per inch of aperture on TeleVue's least expensive model, the Ranger).

In addition to scopes, we also stock all the TeleVue eyepieces, Barlows, and accessories in depth. Be it a Plössl, Nagler, Radian, Powermate, Panoptic, tunable top Paracorr, Gibraltar or Tele-Pod mount, Qwik-Point finder, and more, if it's a TeleVue product, the chances are very good we have it in stock.

It might be a Questar.

For many people, the thought of a 3.5" scope that *starts* at $3395 is enough to curl their toes. But for those who want the best small telescope made, $3395 is a bargain.

Questar 3.5" Standard **$3395**

Solar filters for eyepiece and finder, built-in Barlow, two ultra-premium eyepieces, a velvet-lined hard case, a star chart on the slide-on lens shade with a Moon map beneath – all are standard on a Questar . . . and unavailable from the competition.

Want a Questar, the premier portable telescope? We stock them.

A CM1400 for how little?

Celestron CM1400

We made another special buy on a large quantity of Celestron's 14" Schmidt-Cassegrain German equatorial mount CM1400 telescopes. The normal retail on the CM1400 is $5299 and up. But, once again, our price is too low to print. You'll have to call us at (800) 422-7876 to discover the actual price. While quantities available at this price are large, they're not infinite, so don't miss out.

CCD? We carry Apogee, Meade, and SBIG.

Since we stock almost all available models of the Apogee LISÄÄ, Meade, and SBIG CCD cameras, autoguiders, and accessories, chances are good you won't have to wait to get the camera of your choice. Here are the CCD cameras and guiders that we normally keep in stock and their prices.

Apogee LISÄÄ autoguider or camera	**$1495⁰⁰**
Apogee LISÄÄ color camera	**1395⁰⁰**
Apogee LISÄÄ megapixel camera	**2595⁰⁰**
Apogee LISÄÄ megapixel color	**2595⁰⁰**
Apogee LISÄÄ guider + color	**2690⁰⁰**
Apogee LISÄÄ guider + megapixel	**$3890⁰⁰**
Meade 201XT autoguider	**395⁰⁰**
Meade 208XT autoguider or camera	**495⁰⁰**
Meade 216XT 16-bit camera	**695⁰⁰**
Meade 416XTE camera/guider pack	**1995⁰⁰**
Meade 1616XTE camera/guider pack	**6495⁰⁰**
SBIG ST-4 autoguider or cameraa	**890⁰⁰**
SBIG ST-5C track/accumulate camera	**895⁰⁰**
SBIG ST-237 track/accumulate camera	**1195⁰⁰**
SBIG ST-6B track/accumulate camera	**3025⁰⁰**
SBIG ST-7E self-guiding camera	**2950⁰⁰**
SBIG ST-8E self-guiding camera	**7350⁰⁰**
SBIG ST-9E track/accumulate camera	**3950⁰⁰**
SBIG STV digital video camera/guider	**1595⁰⁰**
SBIG STVD digital video w/LCD screen	**1995⁰⁰**

Celestron NexStar 5? We have 76 in stock!

At the time this was written (6/1), we had 76 Celestron NexStar 5" f/10 go-to computerized Schmidt-Cassegrains in stock for immediate shipment.

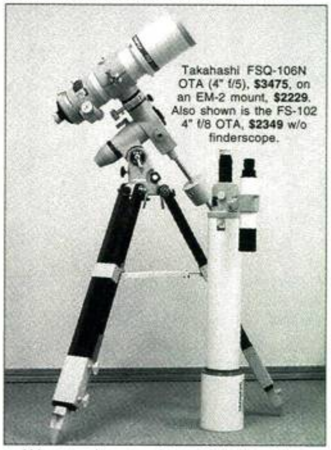
The NexStar 5 has the same built-in 18,473-object database computer as the NexStar 8 on the previous page. It has the same penlight-battery DC operation, the same sleek 21st century styling, the same standard equipment AC adapter and eyeglass-friendly Star Pointer finder. And it's all in a package that's supremely user-friendly and portable.

NexStar 5 **$1199**

It could be a Takahashi refractor.

While many people swear *at* the long delivery times quoted by some premium refractor manufacturers, most knowledgeable astronomers swear *by* the unsurpassed optical quality and fast delivery of the Takahashi apochromatic refractors we keep in stock.

From the 2.4" **FS-60C** OTA at $829 to the 5" **FS-128** OTA at $5249, we stock Takahashi fluorite apochromatic doublet refractors, mounts, and accessories – so we can deliver scopes *fast*. We can also special order larger scopes with 1-3 month delivery times. Why wait for 1-3 *years* to get your apo refractor or mount from another manufacturer? You can be usually be viewing through a truly fine Takahashi apo only a few short days after you order from us.



Takahashi FSQ-106N OTA (4" f/5), **$3475**, on an EM-2 mount, **$2229**. Also shown is the FS-102 4" f/8 OTA, **$2349** w/o finderscope.

We stock complete Takahashi apo scopes on USD mounts with dual-axis 50x sidereal slewing, as well as apochromatic optical tubes to install on your own mount.

We also stock the 22" long Takahashi **FSQ-106N** 4" 4-element f/5 dual fluorite apo refractor OTA, with retractable lens shade, at $3475. It's a great travelling scope. We had 7 in stock as we wrote this on 6/2.

Also in stock is the unique Takahashi **CN-212H** 8.3" reflector ($6999 on an EM-10 mount). It's both a very fast f/3.9 Newtonian for wide field astrophotography *and* an f/12.4 Cassegrain reflector for high contrast visual observing.

If you want a great scope, and want it *now*, it's Takahashi from ***astronomics***.

> About an hour ago the Post Office delivered the Meade illuminated eyepiece I ordered from you only last Monday. I am very impressed with the fast service from you and just wanted to make you aware of this. Initially you were out of stock when I first called to order from you but were very upfront about it. I attempted to order this eyepiece from a company in New York who subsequently placed it on backorder without informing me they did not have this item in stock at the time of the order. I waited 8 days before calling to follow up on the order and was told it would be two more weeks while they ordered it from Meade. I immediately cancelled the order with them and again called you. This time it was available and from there the story has a happy ending.
>
> **Customer Quote of the Month #102**

It could be this 8" *astronomics* exclusive that saves you over 50%!

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Celestron C8 Special Edition, an astronomics exclusive (shown with optional dec motor)

Our 8" Celestron **C8 Special Edition** is built for us by Celestron, exclusively to our specifications. We have 59 available. *No other telescope dealer has it.*

It's an 8" Schmidt-Cassegrain with Starbright multicoated optics and all the most-wanted features and options. Big setting circles, dust covers, and manual slow motion controls are standard. It has an accurate sidereal rate DC drive that's powered by an ordinary 9-volt transistor radio battery for true cordless operation in the field (battery included), *plus separate power adapters for both 110 Volt household AC power in the backyard and 12 Volt DC car battery use out at dark sky observing sites.*

You get a separate wedge with azimuth adjuster. The *adjustable height* heavy duty metal tripod has 2" diameter steel legs. The finder is a big 9 x 50mm. You get *two* Celestron Plössl eyepieces – a 26mm (78x) *and* a 10mm (203x). You also get a Moon filter and a CD-ROM of Celestron's TheSky Level 1 star charting software for your PC.

You won't find this exclusive package of the most-wanted features and accessories on any other telescope. And you won't find any other telescope dealer with anything approaching this unique Celestron package at this low price. *The Celestron C8 Special Edition is an astronomics exclusive!*

Want an eyepiece? We stock 130 different models.

At prices from $37.95 to $595, in focal lengths from 2.5mm to 56mm, chances are good we have the eyepiece that will do what you want, at a price you can afford. Here's a list of the eyepiece brands and types we keep in stock.

Celestron SMA	all focal lengths
Celestron NexStar Plössl	all focal lengths
Celestron Ultima	all focal lengths
Celestron Axiom	all focal lengths
Meade Series 3000 Plössl	all focal lengths
Meade Series 4000 Plössl	all focal lengths
Meade Series 4000 SWA	all focal lengths
Meade Series 4000 UWA	all focal lengths
Pentax XL	all focal lengths
Questar Brandon	all focal lengths
Takahashi LE	all focal lengths
Takahashi ortho	all focal lengths
TeleVue Plössl	all focal lengths
TeleVue Nagler	all focal lengths
TeleVue Radian	all focal lengths
TeleVue Panoptic	all focal lengths
Vernonscope Brandon	all focal lengths
Vixen Lanthanum	all focal lengths

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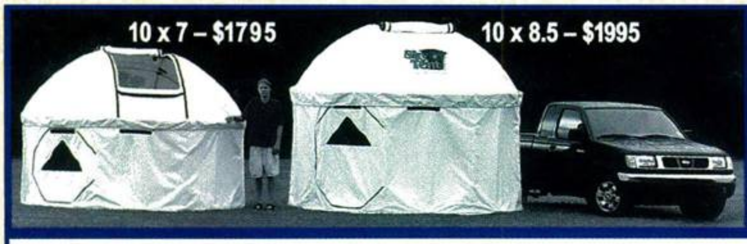

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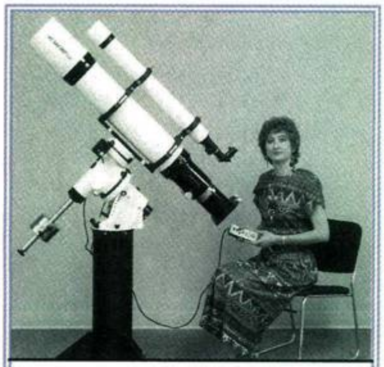

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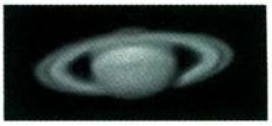

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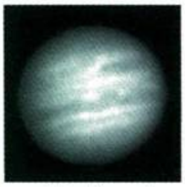

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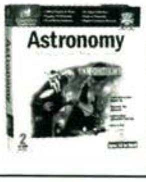

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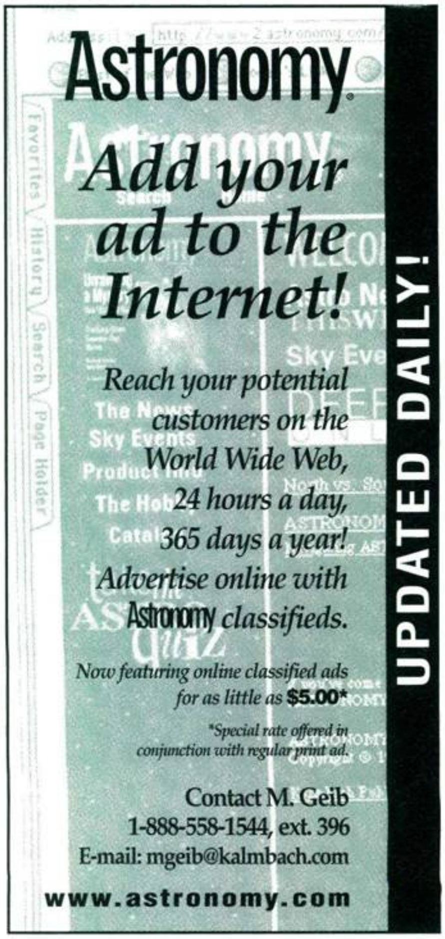

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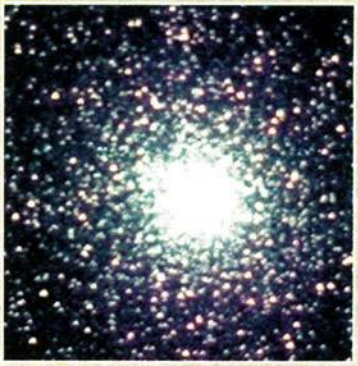

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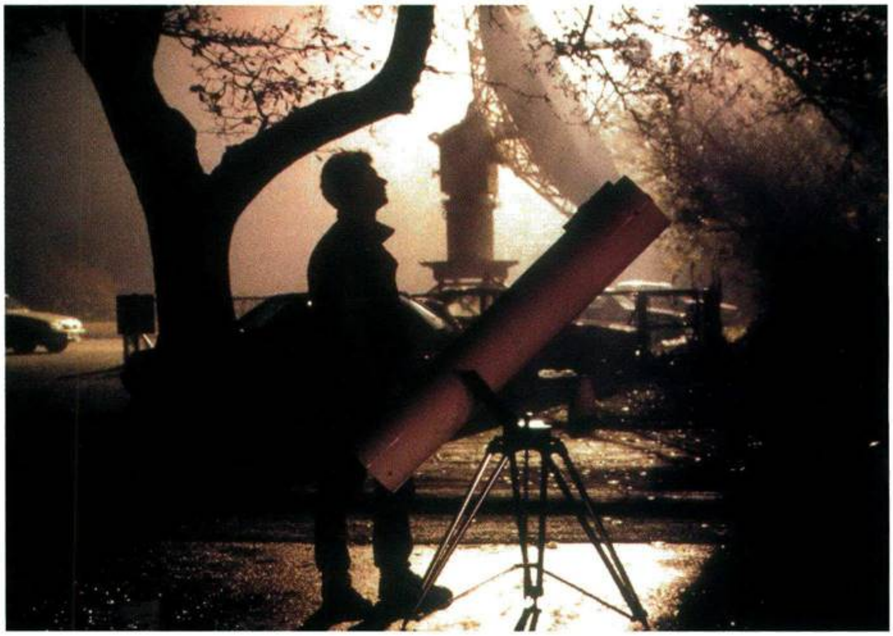
Graham Sinagola

A six-foot satellite dish is juxtaposed near this 6-inch reflector telescope at a star party of the Altrincham & District Astronomical Society in Jodrell Bank, Cheshire, England.

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Arunah Hill Natural Science Center
Cummington, Massachusetts. For information, contact Steve Pielock, P.O. Box 16, Cummington, MA 01026; (413) 772-6715; e-mail, Pielock@acac.umass.edu; website, http://www.reflector.org/ahdays.htm.

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Cherry Springs State Park, Conrad, Pennsylvania. BFSP, Box 947, State College, PA 16801; website, http://www.starparty.homepad.com.

SEPTEMBER 2
Hurricane Ridge Star Party
Olympic National Park, Port Angeles, Washington. Contact John Gallagher, (360) 417-5191; e-mail, jgalla@orca.esd114.wednet.edu.

SEPTEMBER 2
Keystone State Park Star Party
Amateur Astronomers Association of Pittsburgh. Derry, Pennsylvania. Contact Pam Primas, Keystone State Park, RD2 Box 101, Derry, PA 15627; (724) 668-2566; e-mail, kpnature@nb.net.

SEPTEMBER 9
Shreveport Star Party
Worley Observatory, Shreveport, Louisiana. Contact Cran Lucas, (318) 797-1524; e-mail, clucas@softdisk.com; website, http://www.lsus.edu/nonprofit/sbas/.

SEPTEMBER 22 – 23
Craters of the Moon Fall Star Party
Craters of the Moon National Monument, Arco, Idaho. Magic Valley and Idaho Falls Astronomical Societies. Contact Jay Sneddon, (208) 736-2447; e-mail, jsneddon@yahoo.com; website, http://members.tripod.com/mvas/craters.html.

SEPTEMBER 22 – 23
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Palm Canyon Resort, Borrego Springs, California. Contact RTMC, c/o 8300 Utica Avenue, Suite 105, Rancho Cucamonga, CA 91730; e-mail, rstephens@foxandstephens.com; website, http://www.rtmc-inc.org.

SEPTEMBER 22 – 23
Northern Arizona Star Party
Prescott Astronomy Club. Paulden, Arizona. Contact Gary Frey, P.O. Box 1114, Mayer, AZ 86333; (520) 632-7355; e-mail, gfreynpo@primenet.com; website, http://www.pacnet.org.

SEPTEMBER 22 – 24
MERAL/VAAS Convention and Star Party 2000
Charlottesville, Virginia. Contact Ed Walendowski, (804) 975-2888; e-mail, mewalen@rlc.net; website, http://www.cvilleastro.org/.

SEPTEMBER 22 – 24
Astrofest 2000
Chicago Astronomical Society. Camp Shaw-Waw-Nas-See, near Kankakee, Illinois. Strict registration deadline of August 19, 2000. Contact Astrofest 2000, P.O. Box 596, Tinley Park, IL 60477-0596; (773) 725-5618; website, http://www.chicagoastro.org.

SEPTEMBER 22 – 24
White Sands Star Party II
White Sands National Monument. Alamogordo Astronomy Club. Contact Jackie Diehl, WSSP II, P.O. Box 533, Alamogordo, NM 88310; call toll free, (877) 333-6589; or e-mail, wssp@zianet.com; website, http://www.zianet.com/wssp/.

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SEPTEMBER 28 – OCTOBER 1

10th Annual Great Plains Star Party

Scopeville, Kansas. Kansas Astrophotographers and Observers Society. Contact Larry Madison, Great Plains Star Party, 304 Alger Dr., Blue Springs, MO 64014; (816) 229-2394; e-mail, clearskysalways@hotmail.com; website, http://www.icstars.com.

SEPTEMBER 28 – OCTOBER 1

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SEPTEMBER 28 – OCTOBER 1

Whirlpool Star Party

Shannonside Astronomy Club, Offaly, Ireland. Contact David Bell, Bansha, Askeaton, County Limerick, Ireland; e-mail, sdbell@gofree.indigo.ie.

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SEPTEMBER 29 – OCTOBER 1

South Jersey Star Party

South Jersey Astronomy Club. Belleplain State Forest, Woodbine, New Jersey. Contact Paul Ostwald, 23 Isaacs Lane, Egg Harbor Township, NJ 08234; (856) 293-1584; e-mail, paostwald@aol.com; website,http://hometown.aol.com/sjastroc/index.html.

SEPTEMBER 30

Nova Star Party & Telescope Meet

North Virginia Astronomy Club, Crockett Park, Midland, Virginia. Contact Jeff Cook, (703) 524-5333; e-mail, jeff@cookstudios.com; website, http://www.cookstudios.com/nova.htm.

CONTACT

Please submit club announcements four months in advance to Looking Ahead, *Astronomy*, P.O. Box 1612, Waukesha, WI 53187, or to tconley@astronomy.com. Look for additional events at http://www.astronomy.com.

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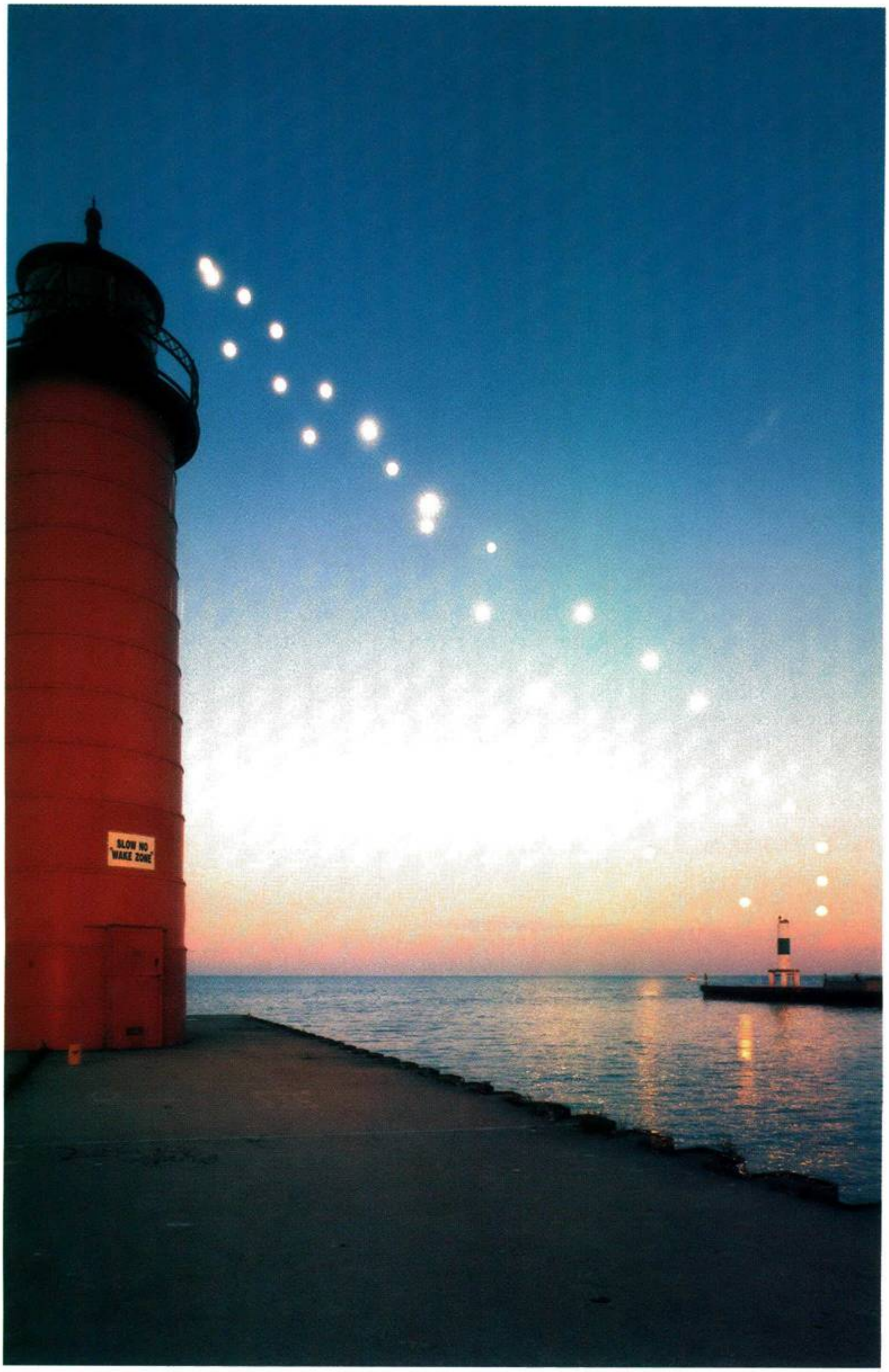
Proper planning and tips from a pro ensure success in photographing an analemma.

▶ An analemma is a series of exposures of the sun, each made at the same time of day on a single sheet of film over a period of one year. My plan called for making 31, one every 12 days, but cloudy skies forced me to skip some appointments and yielded the 27 disks seen here. I used a 4x5" field camera and a 65mm lens to include the wide view of the sky needed to record the sun at its highest and lowest points. To keep extra lights in the sky and foreground from registering during each sun-disk exposure, I equipped the lens with a neutral density filter.

The camera, custom-fitted with a compass, level, and plumb bob, was set up in the same spot on the pier for each exposure and aimed at a previously determined point. The figure eight simply results from the sun appearing at different places in the sky due to Earth's movement. I used Kreb's Suntracker, a well-written DOS program, to calculate the sun's position. Each exposure was made at 13:45 Universal Time per a digital clock checked frequently against Fort Collin's station WWV.

I covered myself by exposing nine sheets of film in rapid succession on each



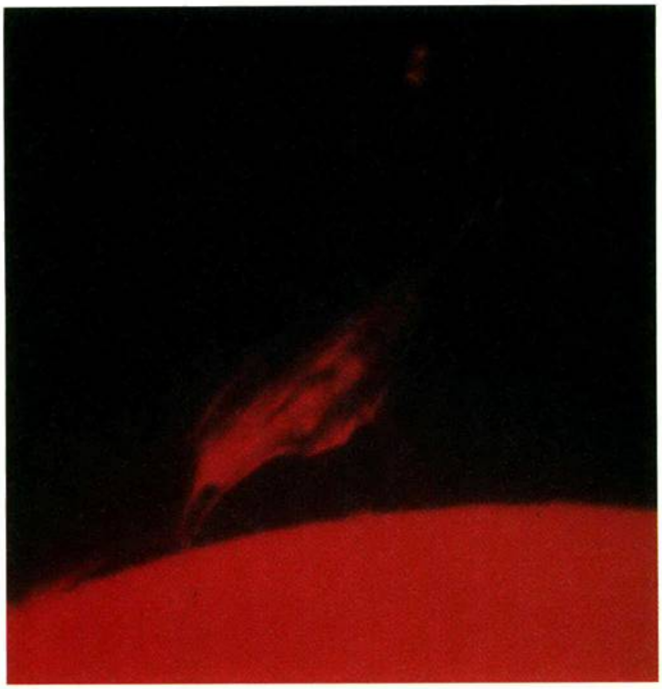
Analemma over Lake Michigan

TOM FULLER

(65mm lens, neutral density filter, Agfa Optima 100 film, 27 exposures, final exposure at f/22 for ⅛ second) scheduled date, starting on August 21, 1998. The first three were shot at my empirically determined sun-disk exposure, the next at one stop over and the last at one stop under. In addition to giving myself plenty of room for disk-exposure error, I now had nine chances at correct foreground exposure and the security of being able to send the film to the processing lab in installments. I refrigerated the holders between shots to preserve the latent images, having chosen Agfa Optima 100 color negative film for its wide exposure latitude.

On August 21, 1999, I made the final exposure at approximately 7:25 P.M. local time. With the sun now behind me to illuminate the lighthouse, pier, and sky, I removed the neutral density filter and made a "normal" shot at ⅛ second and f/22. The disk pattern already exposed on the film appeared between the lighthouse and navigation tower as predicted, but mechanical tolerances in my aiming scheme distorted the analemma from its calculated "bowling pin" shape. However, as I'm a studio photographer rather than an astronomer, I consider the shot to be a success overall. The photograph reproduced here is a straight print from one of the nine negatives (not a composite image) and no digital manipulation was used in its creation. ▣

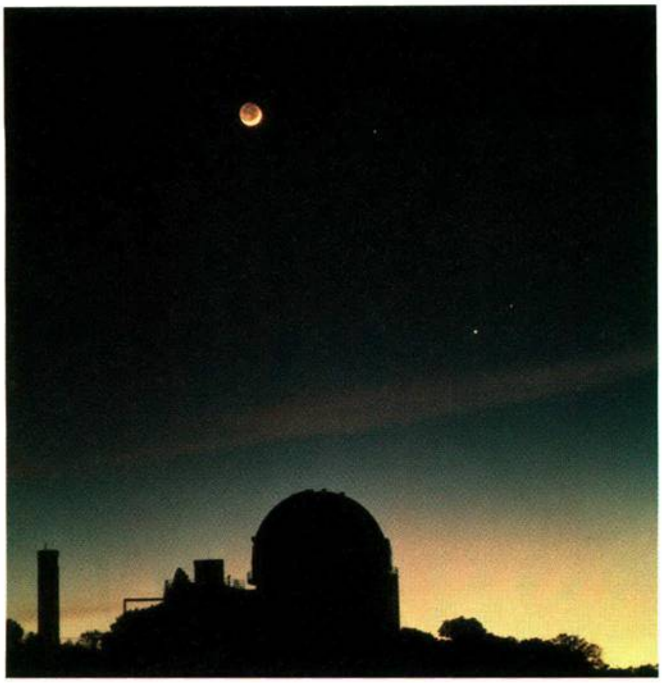
Tom Fuller is a commercial photographer, a college instructor, and a frequent writer for photography magazines here and abroad. He lives in the Milwaukee area and can be reached at fotopro@compuserve.com.



A Prominent Solar Prominence

PHILIP A. SCHMITZ AND THE CROSBY RAMSEY MEMORIAL OBSERVATORY

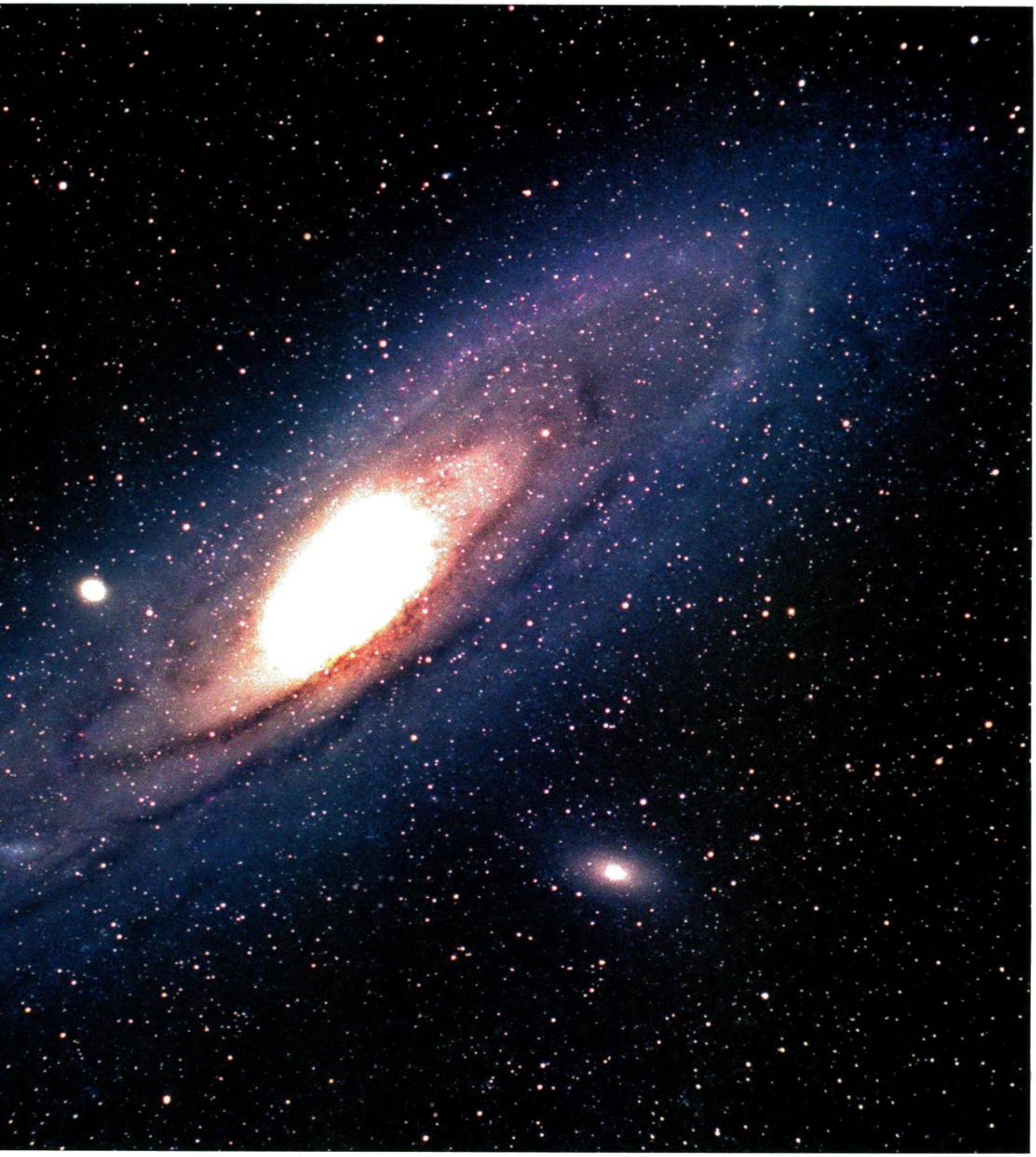
(8-inch refractor, H-α filter, Kodak Elite 100 film, ¼-second exposure taken February 6, 2000)



Moon, Saturn, Jupiter, and Mars Mingle

DETRICK BRANSTON

(150mm lens at f/4, Fuji NPH 400 film, 6-second exposure taken April 6, 2000, from Kitt Peak National Observatory)



The Andromeda Galaxy (M31)

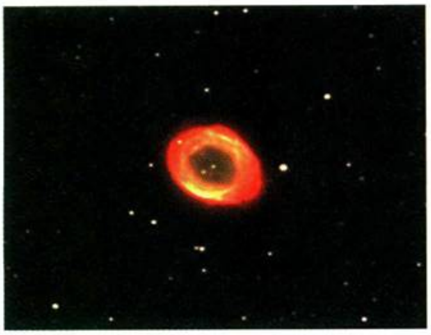
JASON WARE

(5-inch refractor, Kodak PPF 400, 120 format film, composite of two 45-minute exposures)

Ring Nebula, M57

TED WOLFE

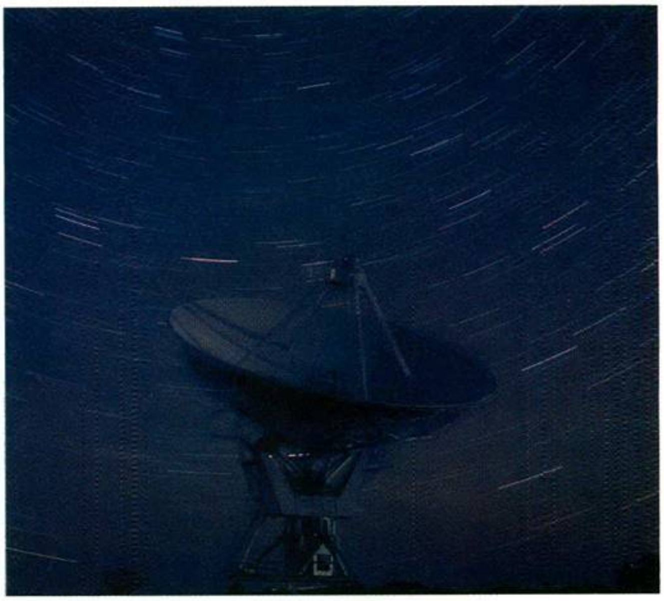
(12.5-inch Ritchey-Chrétien scope, ST8E CCD camera, 30-minute exposure)



Star Trails over the VLA

JOHN CHUMACK

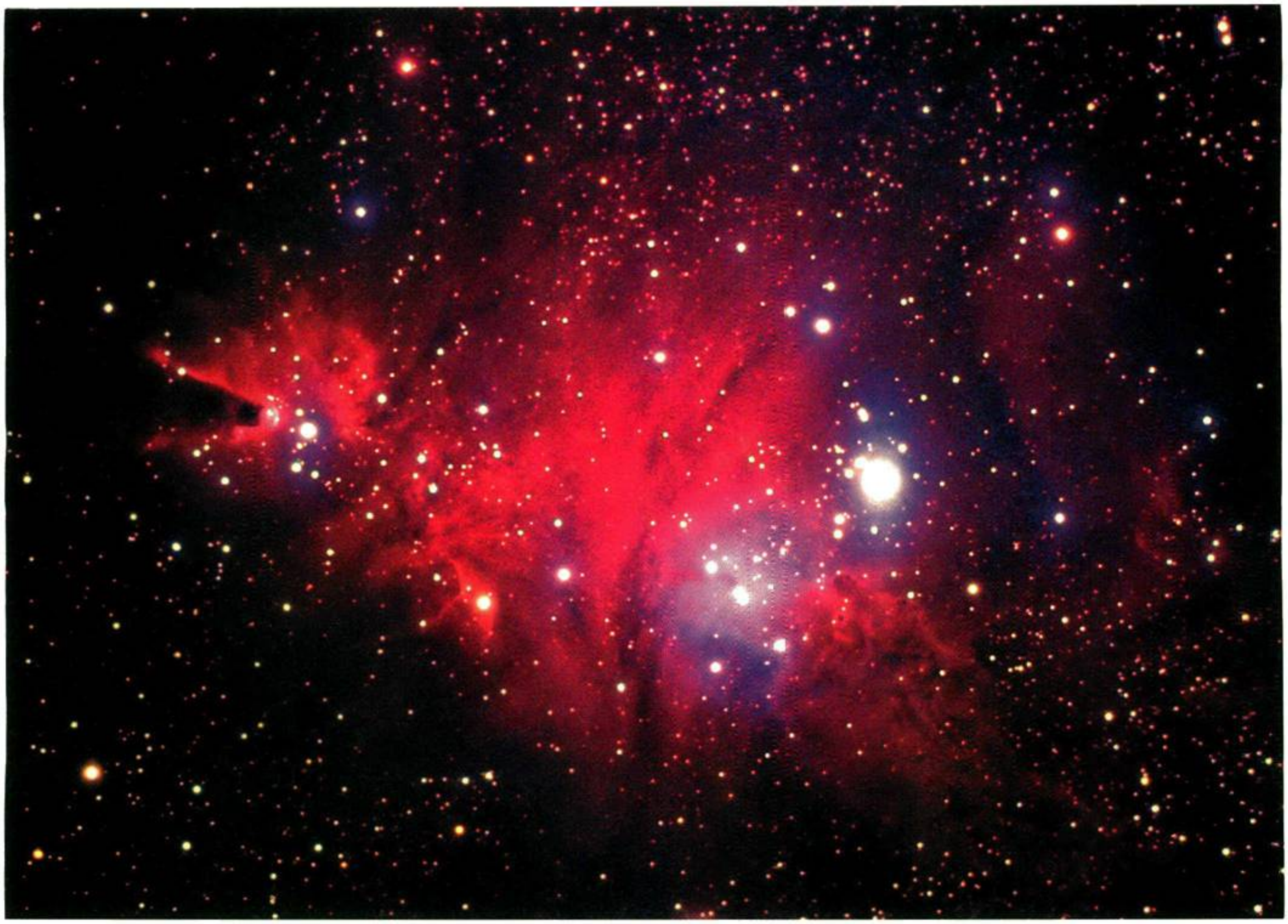
(90mm lens at f/4.5, Fuji NPH 400 film, 15-minute exposure)

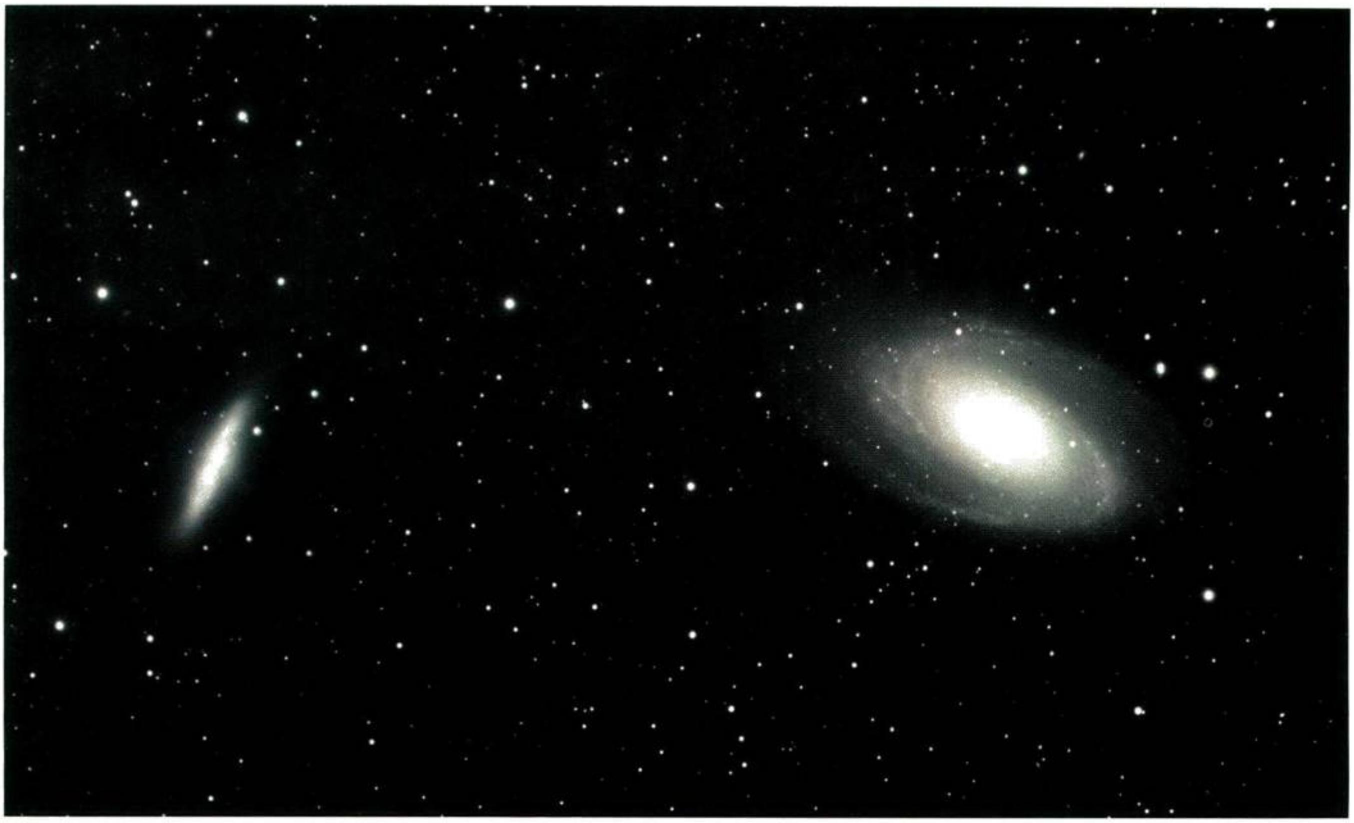


Cone Nebula

ROBERT GENDLER

(6-inch refractor at f/5, ST8E CCD camera; 5-minute red, 5-minute green, 10-minute blue, and 60-minute luminosity exposures)

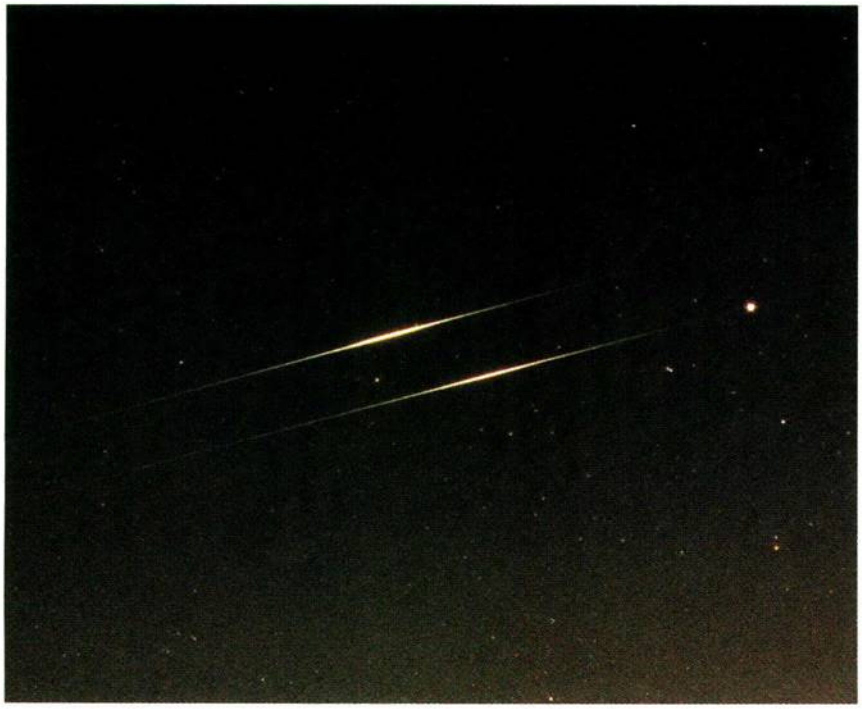




M81 and M82

GREGORY TERRANCE

(6-inch f/7 refractor, IMG1300 CCD camera, composite of five 5-minute exposures)

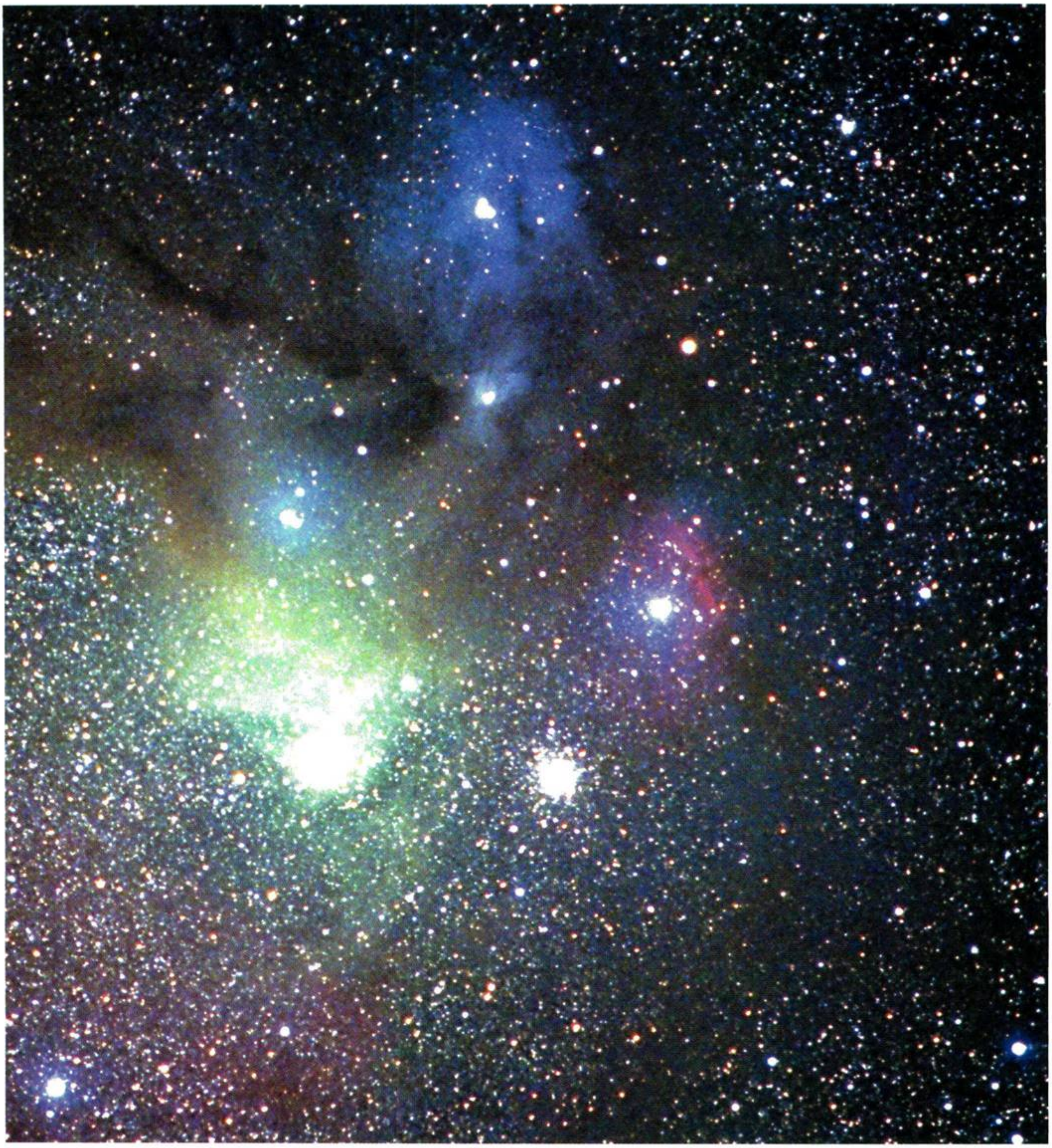


A Double Iridium Flare

DAVID SEWELL

(50mm lens at f/5.6, Kodak Gold 200 film, 1-minute exposure taken May 29, 2000, at 10:23 P.M. EST)

This month's best astrophoto



Rho Ophiuchi Region

MARCO LORENZI AND GABRY FAVRETTO

(180mm lens at f/2.8, composite of two 20-minute exposures on Kodak PJM film and two 20-minute exposures on Fuji SG400 film)

This oft-photographed nebulosity lies about 540 light-years away in the constellations Ophiuchus and Scorpius. Globular cluster M4, the bright star Antares, and emission, reflection, and dark nebulae are all visible.

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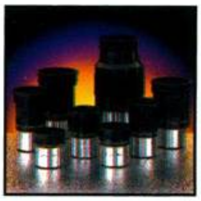

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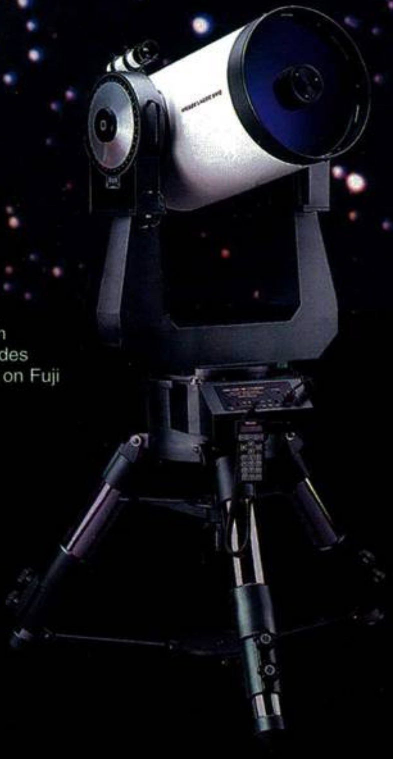

The Trifid Nebula (M20), one of a number of spectacular deep-space objects located in Sagittarius, owes its name to rifts which trisect the southernmost (red) body of the nebula. These rifts, or voids, radiate outwardly from the triple star HN 40, which includes components of magnitudes 6.9, 8.0, and 10,5. Jason Ware obtained this image, a composite of two one-hour emulsions at f/10 on Fuji Super G800, using the Meade 16" LX200 Schmidt-Cassegrain telescope oriented in the altazimuth mode; field rotation was compensated for with the Meade #1222 Field De-rotater.

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